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GAS-FLAME BRAZING OF METALS

by G. A. Asinovskaya

- USSR -

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- USSR -

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PREFACE

In this booklet problems relative to gas-flame brazing with low- and high-melting point solders are elucidated, data necessary for the use of new equipment and apparatus are presented, the technological peculiarities of solders of various metals and alloys are explained, and data on safety techniques are offered.

The booklet is intended for workers and foremen engaged in the field of gas-flame brazing.

INTRODUCTION

The technological process of securing a permanent bond of solid bodies by means of the melting of an intermediate metal or alloy (the solder), with subsequent crystallization of the latter, is called brazing /or soldering; according to the Webster definition, brazing properly applies only to high-temperature soldering, soldering both to high- and low-temperature work. Since a gas flame implies the presence of considerable heat, the term brazing will be used in this translation save where low heats are specifically indicated, or where both high and low heats are specifically included by a single term, and in these instances the term soldering will be used instead./.

Brazing or soldering is widely used in various branches of industry. This process permits one easily to connect metals and alloys heterogeneous in composition, and also non-metallic materials (ceramics, graphite, glass, etc.), among themselves and to metal parts or elements.

Of late years brazing has been replacing welding, simplifying casting and forging. In practice brazed structures in many cases replace complicated castings and forgings. In such branches of industry as automobile, aircraft, and ship-building brazed structures are used to reduce the "dead" weight of the elements, since it is possible to join thin-wall stamped elements by brazing. Aside from this, brazing is widely used for the manufacture and reconditioning of cutting tools, for elimination of defects in castings, for the repair of components, etc.

Welded seams connect elements along the lines of edges or at points. Brazed seams connect surfaces, for which reason they do not yield to welded ones in strength and surpass them in certain cases. The process of brazing is carried out at lower heating temperatures than welding, and consequently it is considerably more productive and more economical.

The danger of annealing, decarbonizing, oxidizing, and warping steel and of producing other defects is considerably lowered when a shift is made from welding to brazing.

But brazed structures not infrequently yield to welded ones in plasticity and toughness, so brazing and welding must be sensibly combined in production.

There are three types of brazing:

1) Non-capillary brazing, in which the solder is introduced from without and ends up in the gap of the joint to be brazed without the involvement of so-called capillary forces; it is on this principle that the process of braze-welding /payko-svarka/ is carried out;

2) Capillary brazing /sweating?/, in which the solder is also introduced from without, but is melted as a result of the heat of the metal to be brazed and enters the gap under the effect of capillary forces; this form of brazing is the most widespread;

3) Reactive-contact brazing, which is carried out through the formation of a liquid low-melting-point alloy between the metals to be joined, without the introduction of a solder.

The process of brazing may be classified according to the method of heating (Figure 1).

The previously accepted division into hard- and soft-soldering, at the basis of which there were placed the properties of the solders used, has lost its foundation.

The former practice was to consider that hard solders have a melting temperature above 500° C, and soft ones lower than 400° C; in addition, that in hard soldering the joint is of considerable strength, reaching 50 kg/mm^2 and higher upon fracture; in soft solder the limit of strength upon fracture does not exceed 5-7 kg/mm^2.

At present there have been developed solders on zinc and aluminum bases which do not correspond to the classification referred to. For example, zinc-tin solders have high strength, but in temperature indices they are closer to soft solders.

In this booklet there is considered only gas-flame brazing, which is the most widespread in individual and small-series production. This process is carried out through the

flame of a gas burner, and it is used in capillary and non-capillary brazing.

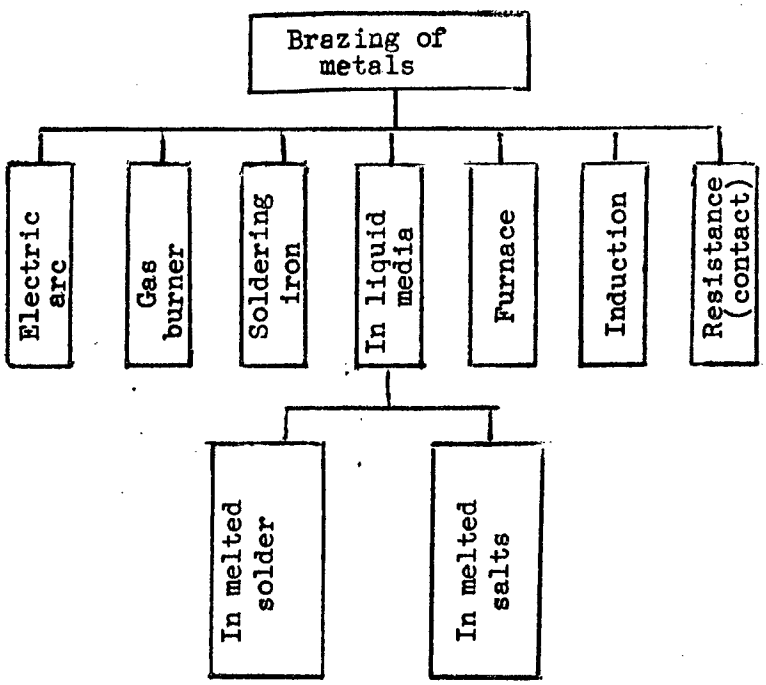


Fig. 1. Classification of process of brazing by methods of heating.

Among the advantages of brazing with the heat of a gas flame are the universality of the process, the possibility of post heating, the absence of limitations on the form and dimensions of the brazed parts, and the absence of need for special, complicated apparatus.

One must consider relatively low productivity and less exact regulation of the degree of heating of the brazed parts as being among the deficiencies of this process.

Yet it is possible to eliminate the deficiencies referred to by automation and mechanization of gas brazing. At present work in this direction is being done by some enterprises and institutes and in particular by the VNIIAVTOGEN /All-Union Scientific Research Institute for the Autogenous Treatment of Metals/.

I. Formation of the Brazed Joint

As was indicated above, capillary brazing is the most widespread; therefore it is with reference to it that there are considered the phenomena taking place upon the formation of a brazed joint. In capillary brazing the process of formation of a brazed joint may be broken down schematically into the following operations:

1) heating of the basic metal to the operating temperature of brazing;

2) heating and melting of solder;

3) wetting of surface of welded metal, spreading solder on it, and filling of gap by solder;

4) interaction of liquid solder with solid basic metal with formation of intercrystalline forms of bonding;

5) crystallization of soldered seam.

In gas-flame brazing the metal to be brazed is heated in the region of the formation of the seam to a temperature close to the temperature of the solder's beginning to melt. In heating of metals and alloys having high coefficients of heat conductivity (for example copper), the area of temperature influence is great and sometimes one does not manage to avoid general heating of the article. Simultaneous with heating of the basic metal by the flame of the burner the solder is heated.

In order to form a brazed joint it is necessary to create conditions ensuring firm intercrystalline forms of bonding between the solder and the soldered metal. To this end first of all it is necessary to bring atoms of the melted metal into close contact with atoms of the surface layers of the hard metal. This condition is ensured if the liquid solder wets the heated-up basic metal.

If one places on a clean metal surface a drop of liquid metal, then depending upon conditions and its properties it may preserve the initial form of a sphere or may spread over the surface of the metal (Figure 2). The second case (Figure 2, b) is characteristic for conditions where the solder wets the basic metal. Metals having a broad capacity of solubility.

But experiments conducted by A. V. Lakedemonskiy and V. E. Khryapin have shown that with the help of specially selected fluxes it is possible also to ensure the process of

wetting in systems not having reciprocal solubility. Lead and iron do not mix either in the liquid, or in the solid state, but with the help of special fluxes the authors achieved full spreading of lead upon iron.

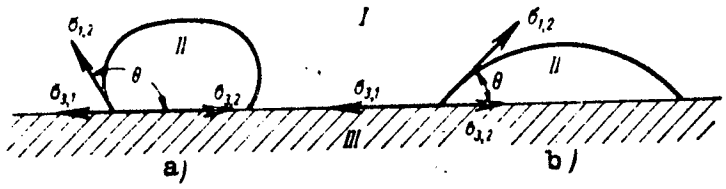


Fig. 2. Dependence of marginal angle of wetting upon the relationship of surface tension forces: a) wetting is absent, $90^\circ < \theta < 180^\circ$; b) wetting takes place, $0^\circ < \theta < 90^\circ$; I) flux; II) solder; III) basic metal.

The degree of wetting is defined according to the magnitude of the marginal angle, formed by the surface of the drop of liquid solder and the line of separation between solid brazed metal and liquid solder. With bad wetting characteristics the angle θ will be more than 90° (Figure 2, a), with good characteristics the angle θ will be less than 90° (Figure 2, b).

In turn the marginal angle is determined by the magnitude of surface tensions at the boundary of solder with the metal to be brazed ($\sigma_{2,\ 3}$), the metal to be brazed and the atmosphere ($\sigma_{3,\ 1}$), and liquid solder with the atmosphere ($\sigma_{1,\ 2}$). Wetting is the greater, the less the magnitude of surface tension $\sigma_{1,\ 2}$ and $\sigma_{3,\ 2}$ is, and the more $\sigma_{3,\ 1}$ is.

Oxides, fats and contaminations present on the surfaces of the metal prevent its wetting with melted solder. Therefore before brazing it is necessary to remove from surface of metal all contaminations. For purification and protection of the surface from the formation of oxides, but also for lowering of surface tension, there are applied special fluxes.

Another condition necessary for obtaining a reliable and even brazed seam, is the spreading of the liquid solder on the surfaces of the brazed metal. Capacity of liquid solder to spread on hard metal is in large degree determined by the roughness of the surface of the latter.

It has been established that solder flows better over a clean and rough surface, but not over a polished one. With a rough surface between elements to be joined there will be formed a great number of capillaries (owing to scratches, projections, and pits, over which the melted solder, under the

influence of the force of surface tension, flows between the elements.

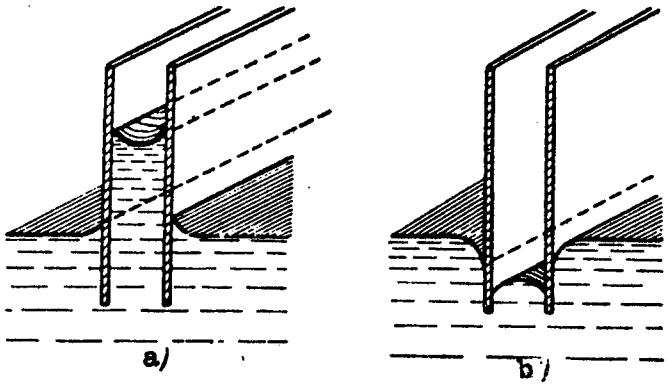


Fig. 3. Conditions for rising of solder in gaps: a) solder wets plates to be brazed; b) solder does not wet plates to be brazed.

In order to ensure the obtaining of a hermetic brazed joint with the necessary mechanical properties the solder should fill the gap formed by the surfaces of the brazed elements.

When two metal plates are brought close together liquid solder will be raised into the gap and will fill it. This condition is ensured in the case where solder moistens metal (Figure 3, a) and which is the main thing, where the surfaces to be brazed form a capillary gap. The height to which the solder will be lifted under the action of capillary forces depends on a whole list of factors and, in particular, is reversely proportional to the size of the gap.

In making a brazed joint one strives to ensure a gap between elements approximately within the limits 0.05-0.15 mm. With smaller gaps solder does not flow and a brazed joint will not be formed; with large gaps flow occurs only by virtue of the force of gravity of the solder, which cannot ensure filling of the capillary.

When one makes certain of all the above-mentioned conditions, the solder interacts with the basic metal over the whole contact surface, which is what brings about a firm metallic bonding between them.

Depending upon the properties of the solder and of the basic metal, but also upon the conditions of the brazing, it is possible to expect the following phenomena at the margin of the melting:

1) dissolving of the basic metal in the liquid solder;

2) reciprocal diffusion (penetration) of atoms of the metals, with formation of a solid solution;

3) reciprocal diffusion with formation of chemical compounds.

The character of the interaction of the basic metal with the melted solder depends on constitution diagram of the system of elements, entering into their composition.

As a result of the first two phenomena the properties of brazed seams are as a rule improved. For example, it is known that copper-phosphorous solders in their initial form are extraordinarily brittle. At the same time brazed seams of copper and its alloys, produced by brazing with these solders, turn out to be more plastic owing to enrichment of the seam with copper. In the structure of a welded joint in copper, executed by means of phosphorous solder (Figure 4), there is distinctly visible in the zone of where the solder melts together with the basic metal a bright strip, representing a solid solution of phosphorus in copper, more plastic than the main mass of seam, which is rich in phosphorus. The bright strip was formed due to the dissolving of copper in the solder. When chemical compounds form at the margin of the melting the plastic properties of the brazed joint are worsened.

Fig. 4. Structure of brazed joint in copper, executed with copper-phosphorus solder (X500): 1) brazed seam; 2) zone of seam which is enriched with copper; 3) basic metal.

A brazed joint will be formed also upon the brazing of metals by means of solders which do not enter into chemical reaction with them and do not dissolve them.

It is known that painstakingly cleaned and fluxed copper is brazed by pure lead, although they do not mix either in a solid nor in a liquid state.

In this case, evidently, firm bondings arise as a result of the convergence of atoms of metals to the distance where interatomic forces operate. To ensure such connections a more painstaking preparation of article to be brazed, and protection of it and the solder from oxidation are necessary since alien inclusions and oxidized films can disturb the contact of atoms of the metals all along the joint. The firmness of these joints is as a rule lower than for those which form by virtue of the appearance of solid solutions or chemical compounds, since in the latter case the appearance of connections takes place analogously with gluing.

II. Combustible Mixtures Used in Brazing

Components of mixtures. In the process of gas brazing the melting of solder and the heating of articles to be brazed are carried out by means of heat, produced by a flame which is formed upon the burning of a combustible mixture. The latter consists of a combustible part and an oxidizer. As oxidizer in brazing we use air and oxygen; as combustible we use acetylene and its substitutes.

In brazing work there are used the following gas mixtures: city or natural gas with air, city or natural gas with oxygen, propane-butane with oxygen, hydrogen with oxygen, acetylene with air, acetylene with oxygen (gas mixtures are given in the order of the increase of the temperature of the flame).

In brazing the gas mixture is selected taking into account production possibilities, the heat conductivity of the elements to be brazed and the properties of the solders used.

Gas substitutes for acetylene in mixture with air are most frequently used in brazing with low melting point solders.

At normal pressure and a temperature of 20° C oxygen is a colorless, transparent gas, odorless and tasteless, with a specific gravity of 1.429 kg/m^3.

The technical oxygen in gas form which is used for cutting, welding and brazing of metals is supplied under State Standard 5583-58 in two sorts: sort A of 99.2 o/o purity and sort B of 98.5 o/o purity.

Oxygen is an energetic oxidizer, and the oxidizing reaction of oxidation in it takes place with the production of a great quantity of heat.

Acetylene is the most widespread combustible in gas brazing. Pure acetylene at room temperature and atmospheric pressure is a colorless gas without odor and taste. Technical acetylene, by reason of the presence of impurities (mainly hydrogen phosphide) has a specific sharp odor. The basic properties of acetylene are set forth in Table 1. In the same place there are set forth the properties of other gases used in brazing. The temperature of the flame of an acetylene-oxygen mixture is the highest of all industrial mixtures of gases with oxygen.

Acetylene for brazing can be secured near the work site in a portable generator or at a factory acetylene station, in

stationary generators, whence it is transmitted by pipe lines to working points. In all cases acetylene moves under low or medium pressure (up to 1.5 kg/cm^2).

According to maximum pressures of acetylene produced generators are divided into three groups:

1) low pressure -- up to 0.1 kg/cm^2;

2) medium pressure -- over 0.1 kg/cm^2;

3) high pressure -- over 1.5 kg/cm^2.

Of late acetylene dissolved in acetone and transported from place of production in special vessels under pressure up to 16 kg/cm^2 (at 20° C) is being used more and more.

In work with dissolved acetylene safety is increased safety and the operative's working conditions are improved.

In brazing acetylene can be successfully replaced by other combustibles, something that, without worsening the quality of brazing and without lowering productivity, permits of a more economic process.

The concept of flame. Flame is formed as a result of combustion of a combustible in gas form, or of the vapors of a combustible liquid, in mixture with oxygen or air.

The appearance of an acetylene-oxygen flame is shown in Figure 5. Depending upon the relationship of consumptions of acetylene and oxygen the flame can be in character either normal (a), carburizing (b) or oxidizing (c).

A theoretically normal flame is secured when in the mixture there is one unit by volume of acetylene to one unit by volume of oxygen. When this is true the acetylene emerging from the nozzle of the burner interacts with the oxygen of the mixture according to the reaction

$$C_2H_2 + O_2 = 2CO + H_2 + 107.58 \text{ kilocalories per gram-molecule} \quad (1)$$

Unburned particles of carbon, made incandescent by heat, which are produced during the combustion reaction form a brilliant white cone visible to the eye -- the "core," the dimensions of which depend on the diameter of the nozzle and the consumption of acetylene; i.e., in practice, upon the number of the burner tip. The flame zone, lying directly behind the core, is saturated with an oxide of carbon and hydrogen, which,

being active reducers, deoxidize heated metal and protect it against oxidation. Therefore the flame zone, located directly behind the core, is frequently called the reducing zone.

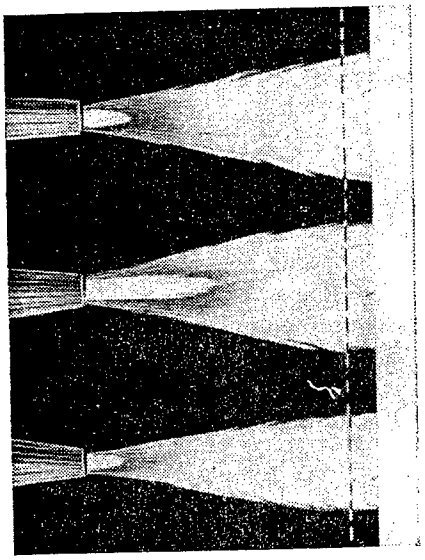


Fig. 5. Appearance of an acetylene-oxygen flame.

The reducing zone has the highest temperature as compared with the remaining parts of flame (see Figure 6).

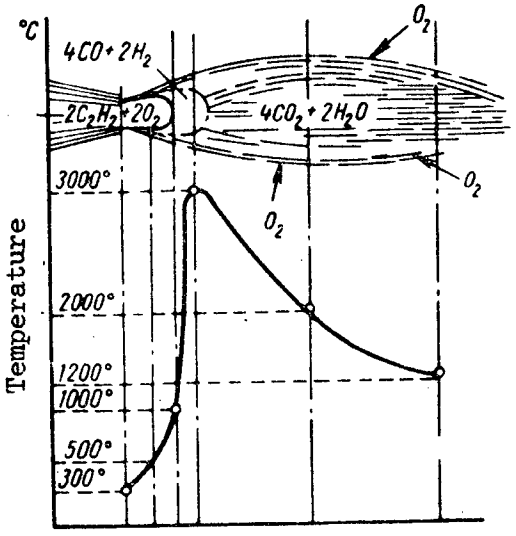


Fig. 6. Curve defining temperature in an acetylene-oxygen flame.

The zone of the flame, located behind the reducing zone, bears the name of the flare.

Behind the reducing zone, in the flare of the flame, there are finally consumed the products of the first phase of combustion of the acetylene, using oxygen from the ambient air according to the reaction:

$2CO + H_2 + 1.5O_2 = 2CO_2 + H_2O + 203.57$ kilocalories per gram-molecule (2)

The flare consists of products of the combustion of carbon dioxide, water vapors, and nitrogen, sucked into the flame together with oxygen from the ambient air. The flare is a colder zone of the flame.

A practically normal flame is secured from the proportion $\beta = \frac{O_2}{C_2H_2} = 1.1 \div 1.2$, i.e., somewhat greater than the theoretical one, since a small part of the hydrogen burns by virtue of the oxygen of the fuel mixture, and also by reason of a certain contamination of technical oxygen.

In a proportion $\beta \geqslant \frac{O_2}{C_2H_2} = 1.3$ and more, the flame takes on an oxidizing character. Hereupon the core becomes shortened, sharpened, with less distinct outlines. The temperature of the oxidizing flame is higher than the temperature of the normal flame. Oxygen, present in excess in the flame, oxidizes the metal.

With consumption of oxygen decreased as compared with the normal (surplus of acetylene) the flame takes on a carburizing ("acetylizing") character. Hereupon the zone of combustion is increased, the core becomes blurred, and behind it there appears an "acetylizing" plume of a yellowish color. In this zone excess acetylene, for the combustion of which there is not enough oxygen, is decomposed according to the reaction:

$$C_2H_2 = 2C + H_2. \quad (3)$$

The carbon being formed can be absorbed by a melted metal for which reason such a flame is called a carburizing one. A carburizing flame has a lower temperature than a normal or an oxidizing flame.

The character of the flame is set by the brazer, as a rule, by eye. After lighting burner the oxygen valve is opened all the way; then the consumption of acetylene is increased to the point where an "acetylizing" plume appears (see Figure 5), after which the consumption of acetylene is decreased till the "acetylizing" plume disappears, thus producing a normal flame.

In order to secure an oxidizing flame, one sets a normal one as is indicated above to start with, and then one decreases the consumption of acetylene until the core is shortened approximately by 1/3 of its length.

The appearance of the flame formed upon burning natural gas (for example, methane) or city gas (type of Moscow) in mixtures with oxygen, differs somewhat from that described. The character of the flame in this case is more complicated to describe as regards its external appearance. The normal flame secured at a proportion of city gas to oxygen (β = 1.3) has dark bluish-orange color and a clearly defined core of light bluish-green color, having the shape of a markedly elongated cone. With a surplus of combustible gas the flare has a bright orange color, a somewhat widened form, and is markedly elongated. The core of the flame is long, transparent, and has a bright green color.

With a surplus of oxygen the flare is markedly reduced in length and takes on a dark blue color. The core also becomes shorter and wider, taking on a light blue color.

A kerosene-oxygen flame, as regards structure and form, does not in any essential respect differ from a methane-oxygen one. The flame normal for brazing occurs at a proportion of oxygen to kerosene amounting to 1.5 m^3/kg.

An acetylene-oxygen flame provides the highest temperature and most concentrated heating.

But in brazing there is not required a high temperature, nor is there required the creation of such a concentrated heat field, as in welding, since melting of comparatively low melting-point solder ought to occur through the heat of the metal to be brazed without melting of the latter. Therefore heating is carried out by the outer flare of the flame, having a temperature on the order of 2,000-2,500° C.

As the process of brazing takes place at temperatures of 1,000° maximum, as compared with gas welding the possibilities of using gas substitutes for acetylene with lower flame temperatures, and also the use of air instead of oxygen are considerably expanded.

The speed of heating in brazing is determined by the effective power of the flame, which consists of the amount of heat introduced into the heated metal in a unit of time. The effective power of the flame depends basically upon the consumption of combustible gas. Thus by regulating the expenditure of combustible one may select an effective power of flame equivalent to the power of an acetylene flame.

The relation of the consumption of combustible substitute V, to the consumption of the acetylene replaced by it,

V_a, is called the coefficient of replacement of acetylene by other fuels.

The coefficient of replacement of acetylene by other combustibles is expressed by the equation

$$\psi = \frac{V_s}{V_a} .$$

The value of the coefficient of replacement of acetylene by other combustibles in brazing is given in Table 1.

In Figure 7 there is presented a graph for determination of the consumption of the acetylene-substitute combustible which upon burning in mixture with oxygen (at a working relationship of the gases in the mixture) gives an effective power of flame equal to the power of an acetylene-oxygen flame with β = 1.15 (β is the datum for kerosene in kg/kg).

Table 1. Properties of Combustibles

Designation and composition of combustible in percentages of volume	Specific gravity at 20° C and 760 mm mercury column in kg/m³	Lowest calorific value at 20° C and 760 mm mercury column in kilocalories per m³	Temperature of flame in mixture with oxygen in degrees C
Acetylene C_2H_2	1.09	12,600	3100-3220
Methane CH_4 (natural gas)	0.67	8000	2000-2200
Coke gas: 40-60% H_2; 20-30% CH_4; 1.5-4% C_mH_n; 5-12% CO; 0.4-1.0% O_2; 3-17% CO_2 и N_2	0.4-0.55	3500-4400	2000-2200
City gas (Moscow type): 7-20% H_2; 15-60% CH_4; 5-7% C_mH_n; 5-15% CO, remaining CO_2 and N_2 ...	0.8-1.05	4100-5000	2000-2300
Propane-butane mixture: 85% C_3H_8; 12% C_4H_{10}; до 3% C_2H_6...	1.2	21,200	2100
Kerosene	0.82-0.84 kg per cubic decimeter	10,000-10,200 kilocalories per kg	2400-2500

Continuation of Table 1

Designation and composition of combustible in percentages of volume	Limits of explosiveness (% content of combustible) by vol. in mixture with		Proportion between oxygen & combustible in the mixture m3/m3	Coefficient of replacement of acetylene
	air	oxygen		
Acetylene C_2H_2	2,2—81,0	2,8—93,0	1,1—1,2	1
Methane CH (natural gas)	4,8—16,7	5,0—59,2	1,5—1,6	1,6
Coke gas:				
40—60% H_2; 20—30% CH_4; 1,5—4% C_mH_n; 5—12% CO; 0,4—1,0% O_2; 3—17% CO_2 и N_2	7,0—21,0	—	0,8—0,9	3,2
City gas (Moscow type):				
7—20% H_2; 15—60% CH_4; 5—7% C_mH_n; 5—15% CO; remaining CO_2 и N_2	3,8—24,8	10,0—73,6	1,2—1,3	1,95
Propane-butane mixture:				
85% C_3H_8; 12% C_4H_{10}; до 3% C_2H_6	1,5— 9,5	3,0 4,5	3,4—3,6	0,6
Kerosene	1,5--5,5	—	1,7—2,4 m3/kg	1,3 kg/m3

Experiments have shown that with an equivalent expenditure of combustible the speed of brazing practically does not change upon shifting from acetylene to gas substitutes for kerosene; nor does the quality of the seam change with this shift, and at the same time the probability of overheating and burning articles decreases.

The use of the combustibles mentioned in substitution for acetylene in brazing produces a notable economic effect;

furthermore, in whole list of fields they are more readily available than acetylene.

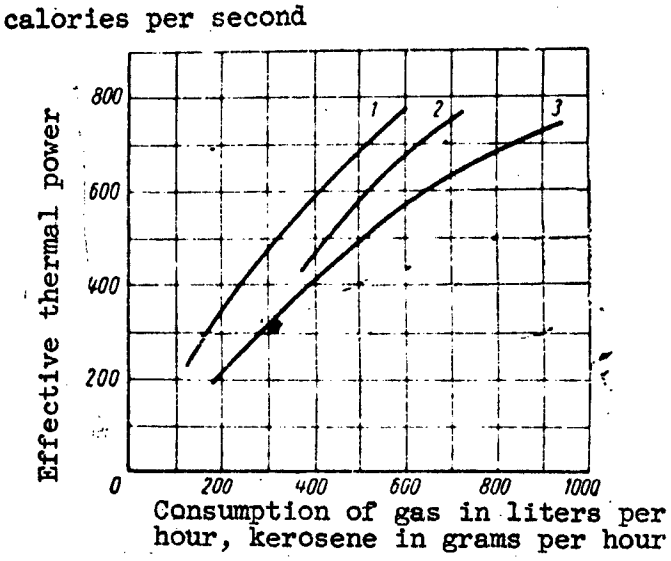


Fig. 7. Graph for determination of equivalent consumption of combustible substituting for acetylene: 1) acetylene, β = 1.15; 2) kerosene, β = 2; 3) city gas, β = 1.3.

III. Equipment for Gas-Flame Brazing

In manual gas-flame brazing the heating is chiefly carried out by welding burners. In automatic brazing linear multi-nozzle burners are used. The blowtorches used earlier are in most cases supplanted by burners.

1. Manual Gas Burners

Gas burners used in manual brazing are universal, are convenient in work, and it is possible to heat components easily with them. With the help of the burner one creates local warm-up in the area of the brazed seam, ensuring the best filling with solder of the gap between brazed surfaces, at the same time provoking overheating of adjacent parts.

According to principle of action three types of burners are distinguished: injector burner, working on combustible gas of low and average pressure; non-injector ones (even-action apparatus), on combustible gas of average or high pressure, and external displacement ones, on low or average pressure.

Acetylene-oxygen burners, or burners using gas substitutes for acetylene in mixture with oxygen, work chiefly on the principle of injection or equal pressure. These, as a rule, are ordinary welding burners. In the Soviet Union such burners are put out by specialized factories.

Burners working on mixtures of combustible gas and air are not put out by industry but are designed and are manufactured by consumer factories. Burners of this type, as a rule, are built on the principle of external- or internal-nozzle mixing. The external appearance of a burner (fevka) working on a mixture of city gas (Moscow type) with air on the principle of internal-nozzle mixing is shown in Figure 8. In this case compressed air and combustible gas pass via corresponding channels and are mixed as they exit into the mouthpiece. In external mixing gases are united in the atmosphere, emerging each from its own channel through a corresponding nozzle. In particular, such burners are used in brazing wind instruments. In these burners air may be supplied under pressure from a compressor or is sucked from the surrounding ambient.

At present in domestic industry the widest use is made of injector burners, a theoretical diagram of which is given in Figure 9. Oxygen under pressure up to 4 kg/cm^2 proceeds via channel 4 into injector nozzle 5. Upon the emergence of oxygen at great speed from the opening of the nozzle there is created a rarefaction in the acetylene channels, in consequence

of which acetylene is sucked into the mixing chamber 10, where it forms with oxygen a combustible mixture. The latter, passing via tube 11 of the tip, forms the welding flame after emerging from the mouthpiece 12.

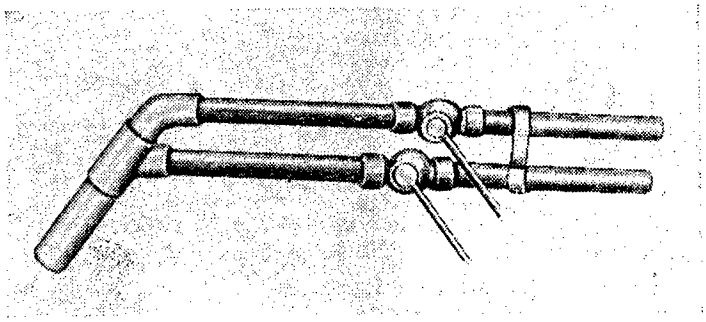


Fig. 8. Burner for city gas of Moscow type in mixture with air.

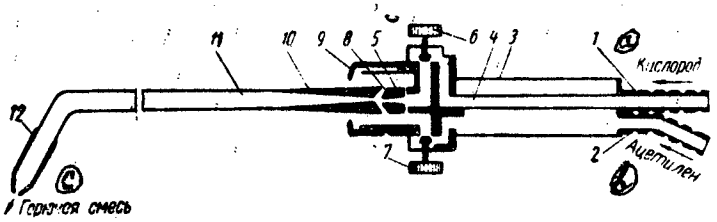


Fig. 9. Diagram of injector burner: 1) Oxygen inlet pipe; 2) acetylene inlet pipe; 3) body of burner; 4) oxygen channel; 5) injector; 6) oxygen valve; 7) acetylene valve; 8) opening into the mixing chamber for acetylene; 9) adjustable nut; 10) mixing chamber; 11) tube; 12) mouthpiece. a) Oxygen; b) Acetylene; c) Burning mixture.

Most widespread in domestic industry are the acetylene-oxygen burners of type GS-53 and GSM-53. Of late there have been released the new burners "Moscow" and "Baby."

In the GS-53 burner set (Figure 10) there are seven interchangeable tips, Nos 1-7, consuming from 50 to 2,800 liters of acetylene per hour.

The GSM-53 welding burner is intended for brazing the thinner sort of articles. The burner is supplemented by four interchangeable tips (No 0, 1, 2 and 3) consuming 20 to 400 liters of acetylene per hour.

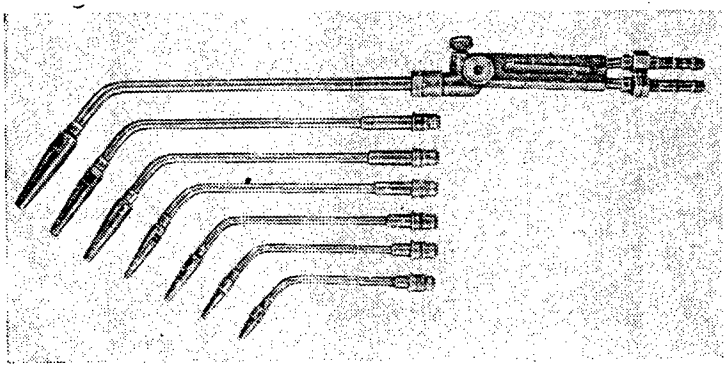


Fig. 10. External appearance of burner GS-53.

The technical characteristic of burners GS-53 and GSM-53 are set forth in Table 2.

Table 2. Technical Characteristic of Tips of Burners GS-53 and GSM-53

No. of burner tip	Operating pressure of oxygen in kg/cm^2	Consumption in liters per hr	
		oxygen	acetylene
0	0.5-4	22-70	20-65
1	1-4	55-135	50-125
2	1.5-4	130-260	120-240
3	2-4	260-440	230-400
4	2-4	430-750	400-700
5	2-4	740-1200	670-1100
6	2-4	1150-1950	1050-1750
7	2-4	1900-3100	1700-2800

Burners of "Moscow" and "Malyutka" types are more resistant to blowbacks and stabler in operation as compared with GS-53.

These burners are supplemented by single-flame mouthpieces. At the same time, in brazing articles of especially large over-all section it is expedient to use sieve mouthpieces (Figure 11), which form a soft flame, widening downward at a small angle. As a result there is ensured a more uniform heating of the article and danger of overheating is reduced. Furthermore, during use of sieve mouthpieces the effective power of the flame is increased, since the process of heating can be carried out with the mouthpiece nearer to the article brazed and without fear of overheating by doing so.

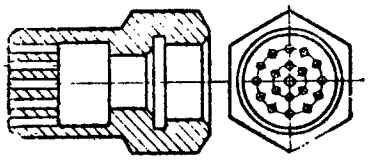


Fig. 11. Sieve mouthpiece.

For work on gas substitutes for acetylene together with oxygen there is used the barrel of the standard burner GS-53, to which are joined special NZP tips, similar in construction to tips for work on acetylene. Dimensions of holes in mouthpieces, injectors and mixing chambers of NZP tips are selected in such fashion as to ensure for each number an effective power of flame equivalent to that for the same number of tip working on acetylene (Table 3).

Table 3. Technical Characteristic of NZP Tips

No. of tips	Consumption in liters per hour			
	methane (natural gas)	coke gas	city gas (Moscow type)	propane-butane mixture
0	40—120	75—230	50—150	20—50
1	120—280	230—520	150—340	50—120
2	210—530	500—990	340—630	115—230
3	500—810	930—1550	600—980	215—350
4	800—1300	1540—2450	980—1560	350—550
5	1100—1870	2080—3460	1350—2220	474—800
6	170—2900	3200—5380	2120—3520	730—1200

Note: Pressure of combustible gas should be not less than 50 mm water column.

Burners working on gas substitutes for acetylene in mixture with oxygen can be prepared through comparatively simple alteration from standard acetylene-oxygen burners.

The principle of equal pressure (non-injector) is used in the burner GAR-2-56. Burners of this type have, as compared with injector ones, a number of advantages, the most essential of which is the possibility of accurate adjustment and stability of maintaining the proportion of gases in the combustible mixture. But to feed them acetylene of medium pressure is necessary.

The burner GAR-2-56 consists of the barrel of the injector burner GS-53 plus seven interchangeable tips in which the construction and dimensions of the mixing chambers are modified.

Just as with the burner GS-53, the burner GAR-2-56 has a normalized scale of power of flame running from 50 to 2,800 liters per hour of acetylene (Table 4).

Table 4. Technical Characteristics of Burner GAR-2-56

No. of burner tip	Operating pressure of oxygen and acetylene in kg/cm²	Consumption of acetylene (power of flame) in liters per hour	Consumption of oxygen in liters per hour	
			for β = 1.3÷1.35 (with completely open valves	for β = 1.1 (normal flame)
1	0,45–1,2	50–120	65–160	55–130
2	0,5–1,2	120–240	160–320	130–265
3	0,55–1,2	240–400	320–530	265–440
4	0,6–1,2	400–700	530–900	440–750
5	0,6–1,2	680–1100	900–1450	750–1200
6	0,6–1,2	1050–1750	1400–2300	1150–1960
7	0,6–1,2	1700–2800	2300–3650	1900–3100

The burners work in the following way: Acetylene and oxygen under identical pressure proceed from a special regulator of DKR type into the mixing chamber. The latter has a lateral calibrated aperture for acetylene and a central one for oxygen. At the exit from the mixing chamber there is a small conical expansion.

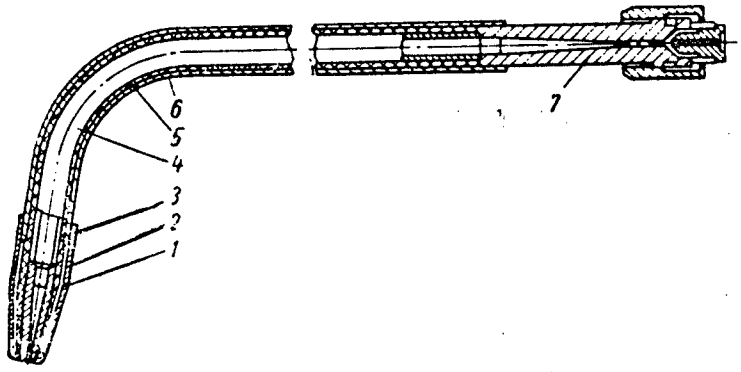


Fig. 12. NAT heat-resisting tip.

The combustible mixture which is formed in the mixing chamber, proceeds further into mouthpiece, after exiting from which it forms the welding flame.

After insignificant changes in diameters of channels, equal-pressure equipment can also be used for gas substitutes for acetylene.

In brazing and welding of cast-iron large-dimension articles the burner heats up from reflected heat and works unsteadily with "cotton-balling." Under these circumstances it is recommended that NAT heat-resisting tips, which can be joined to the barrel of GS-53 or "Moscow" burners, be used.

The tip (Figure 12) consists of a tapered copper mouthpiece 1, brazed with high-melting-point solder to the copper tube 4, asbestos corded insulation 5, a layer of mica 2, a housing of heat-resisting steel 3, a protective tube 6, and a mixing chamber 7. The asbestos insulation and the protective housing protect from heating the gas mixture passing through the channel of the mouthpiece; the brazed connection of the mouthpiece with the copper tube of the tip promotes increase of heat removal from the front end of mouthpiece. In this way there is ensured a stable composition of the gas mixture and steady combustion without interruption in the cooling of the tip.

In using burners working on combustible in gas form, it is necessary to observe the following main rules:

1) to see to proper connection of hoses to burner, reducers, and other devices; airtight seal of all these must be painstakingly checked before lighting the burner;

2) first attach to burner the hose for oxygen; before attaching the hose for combustible gas one should check for presence of suction in the gas channels (on injector equipment);

3) upon lighting flame of burner one should first open the oxygen valve (not completely), and then the valve for the combustible gas; upon extinguishing, the reverse, first shutting off the combustible gas, and then the oxygen;

4) periodically one should check tightness of the threaded joint of the mouthpiece and the adjustable nut of the mixing chamber, since as a result of heating these may loosen;

5) in prolonged continuous work the mouthpiece must be periodically cooled in water; before submersion in water it is necessary thoroughly to shut off the valve for the combustible gas, but to leave the valve for oxygen a little open to prevent entrance of water into the burner.

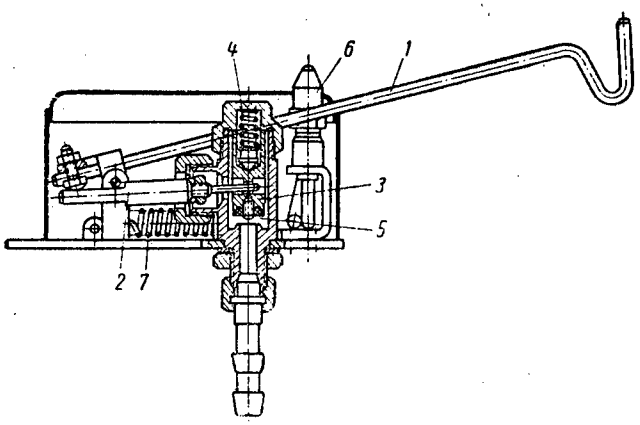


Fig. 13. Construction of the acetylene chamber of an economizer.

The most frequently encountered malfunctions in the work of burners, and the methods for their removal, are set forth in Table 5.

Table 5. Malfunctions in Work of Burners and Methods for Their Removal

Malfunctions	Causes	Methods for Removal of Malfunctions
Looseness in valve seats	Drying out and play in valve seats	Tighten valve seat nuts or add lining (corded asbest impregnated with paraffin)
Absence of suction in channel for combustible gas	1. Obstruction of channels of mouthpiece, mixing chamber, or injector	1. Blow through these channels in the direction the reverse of the usual flow of gas, and if necessary clean with a pure copper or aluminum wire of appropriate diameter
	2. Weakening of adjustable nut of mixing chamber	2. Tighten adjustable nut
Cotton-balling	1. Change in composition of gas (in case of city gas)	1. Affix smaller mouthpiece

Malfunctions	Causes	Methods for Removal of Malfunctions
	2. Oxygen escaping under injector	2. Grind injector, tighten adjustable nut of mixing chamber
Breaking-off flame	Change of composition of gas (in case of city gas)	Affix larger mouthpiece

In brazing work there are frequent interruptions evoked by the need to add solder, turn elements over, affix attachments, and so forth. Since usually these interruptions are brief, the workers do not extinguish the burner.

In order to prevent excessive consumption of gases at the brazer position there has been devised a special instrument -- the economizer. Oxygen and acetylene enter the instrument, where a part of them is passed into a special small burner, forming a pilot flame, while the main mass of gas goes onward into the welding burner. In Figure 13 there is shown a cut of the acetylene chamber of the EGT-1-56 economizer.

At breaks in work the brazer hangs the burner on the hook of lever 1. Under the effect of the weight of the burner level 1 turns on its axle and frees lever 2. Valve 3, under the effect of coil spring 4, is lowered onto saddle 5 and shuts off the passage of acetylene, passing into the economizer through the exit nipple. At the same time part of the acetylene continues to pass into the small burner 6. The oxygen chamber is arranged analogously. Thus upon a break in the work the flame is extinguished, and only the pilot flame of burner 6 is burning. Upon resumption of work the brazer removes the burner from the hook of the economizer and under the effect of the return spring 7, lever 2 raises valve 3. The gas mixture passes into the burner and is lighted from the pilot flame.

2. Burners on Liquid Combustible

For brazing there are used burners working on liquid combustible (kerosene, gasoline) in mixtures with oxygen and air. This combustible is cheaper and more readily available. Working with such burners is somewhat more complicated than with burners, working on gas combustible.

At present there are put out two types of burners for use on liquid combustible with oxygen, the GKU-55 and the GKR-57.

The universal welding burner GKU-55 is shown in fig. 14. The principle of the action of the burner is as follows: Oxygen from a vessel enters the body of the burner through a hose attached to nipple 1, then passes via pipe 2 into pipe 3 which is within the vaporizer 4, and through the injector 5 into the mixing chamber 6.

Kerosene passes from a tank via a durite hose to nipple 7, then via tube 8 it passes through the asbestos web 9, which is coiled upon tube 3, where it is evaporated through the action of the flame of the warmup nozzle 10.

The kerosene vapors are mixed with oxygen which issues at great speed from the injector into mixing chamber. The combustible mixture which forms passes through the mouthpiece and emerges into the atmosphere. Part of mixture is directed into nozzle 10 to heat the evaporator.

The supply of combustible is regulated by knob 11, upon rotation of which tube 3 for oxygen shifts along its axis, changing the size of the gap between the end of the injector and the edge of the mixing chamber. Stop valve 12 serves to cut off the supply of kerosene in the evaporator during breaks in work.

Burner GKU-55 is equipped with six mouthpieces (four single-perforation and two sieve ones).

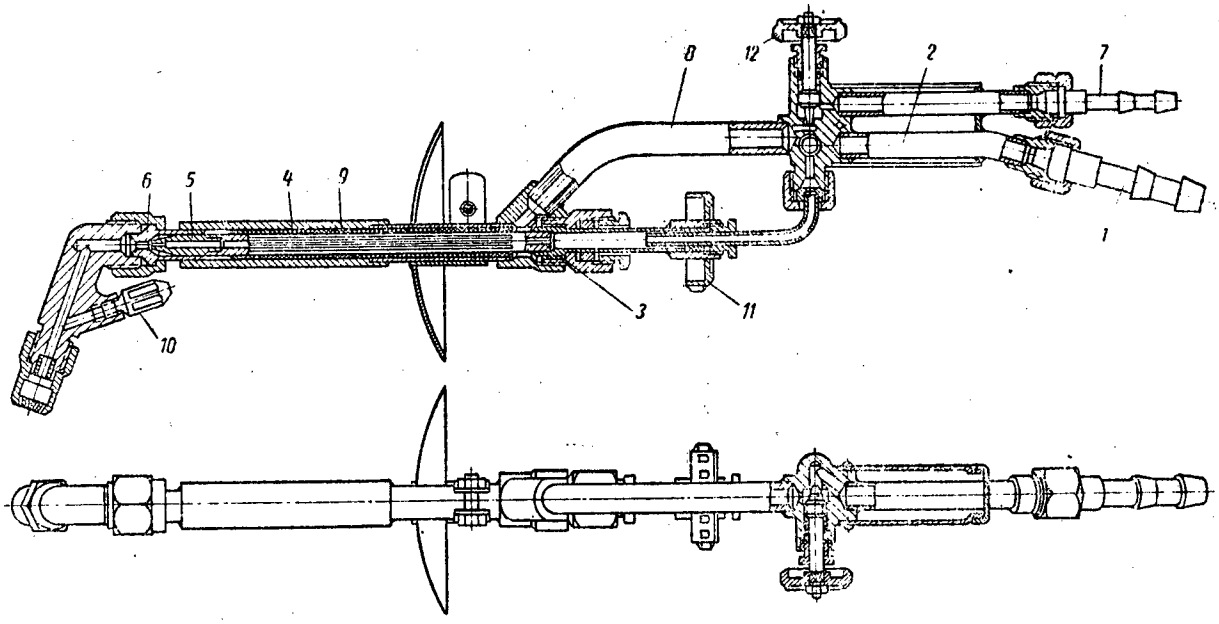


Fig. 14. Kerosene-oxygen burner GKU-55.

Kerosene is passed into the burner from a tank of 5-liter capacity by an air pump, creating an excess air pressure above the liquid. Kerosene passes through the feed valve and hose into burner.

In effective heat power of flame the GKU-55 burner is equivalent to an acetylene-oxygen burner with tips No. 2 and 7 (table 6).

Table 6

Basic data on kerosene-oxygen burner GKU-55

No. of mouth-pieces	Diameter of spray nozzle in mm	Kerosene		Oxygen	
		Pressure in tank in kg/cm^2	Consumption in kg/hour	Pressure in kg/cm^2	Consumption in m^3/hour
Single-perforation					
2	2,5	1,5—3	0,16—0,46	3	0,30—0,80
3	2,5	1,5—3	0,3—0,8	3	0,5—1,4
4	2,5	1,5—3	0,4—1,0	3	0,7—1,8
5	2,5	1,5—3	0,6—1,5	4	1,0—2,7
Sieve					
4—5	3	1,5—3	0,67—1,9	4	1,2—3,2
6—7	3,7	1,5—3	1,5—4,0	4	3,2—7,2

Main deficiency of this burner is complexity of ignition (special measures for initial heating of the evaporator are necessary). Furthermore, the presence of the asbestos web, warm-up nozzle, evaporator tube, and shield increases the weight of the burner.

The deficiencies enumerated are eliminated in burner GKR-1-57 (fig. 15), operating on the principle of the atomization of kerosene by oxygen and subsequent evaporation in the internal cavity of the mouthpiece through spontaneous heating.

While the burner is working combustible from the tank passes via the hose into filter 11, housing 2, and through regulating valve 10 into pipe 9 and onward into the spray mechanism 8 of the heat 5. Oxygen from the hose, surmounting the resistance of the return spring of valve 1, passes into casing 2, valve 3, tube 4 and the spray mechanism 8.

Issuing from the lateral holes of the atomizer, the oxygen atomizes the stream of combustible. The atomized mixture which forms, passes via the cylindrical channel through the cut-off 7 into the internal cavity of the mouthpiece 6, where, coming into contact with the

heated wall of the mouthpiece, it is evaporated and emerges through holes in the mouthpiece.

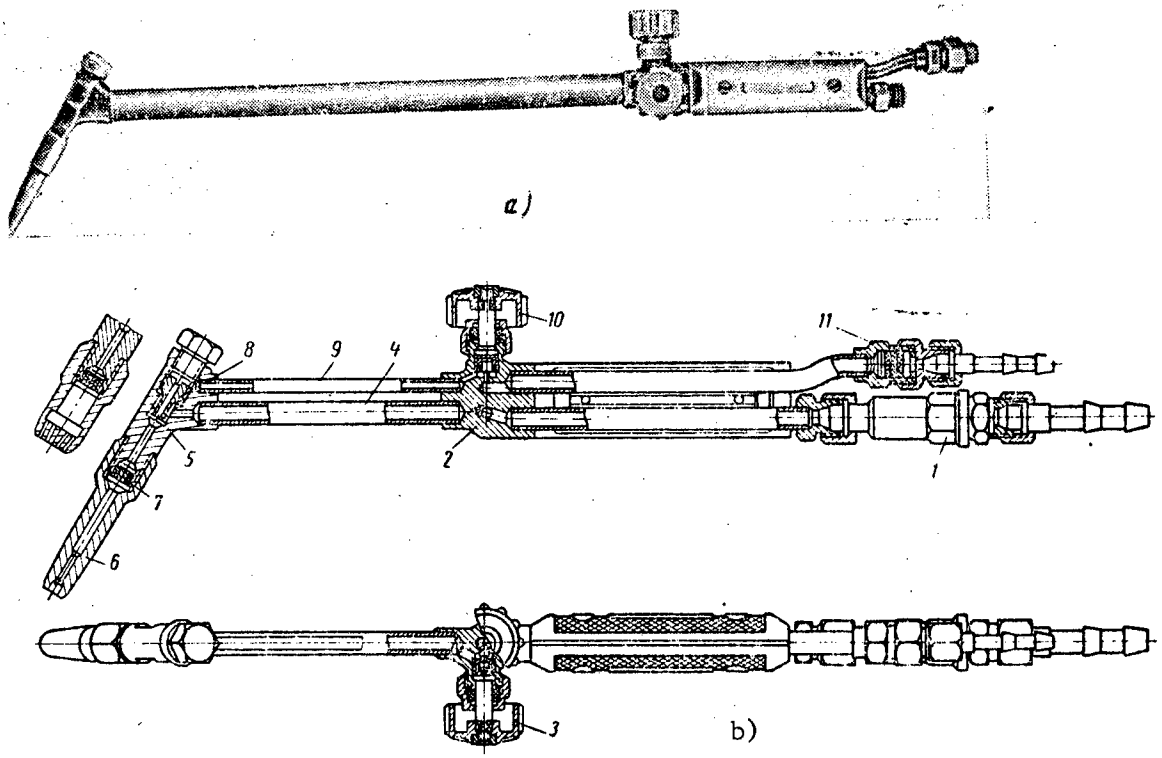


Fig. 15 Kerosene-oxygen burner GKR-1-57.
a) external appearance; b) construction of burner

The burner is furnished with three single-flame and two sieve mouthpieces, ensuring a wide range of adjustment of power of flame with a consumption of combustible from 0.3 to 3.4 kg/per hour (table 7), which corresponds in heat power of flame to tips No. 3--7 of burner GS (table 2).

Table 7

Technical characteristics of burner GKR-1-57

No. of mouth-pieces	Kerosene		Oxygen	
	Pressure in kg/per hour	Consum-ption in kg/per hour	Pressure in kg/ cm^2	Consum-ption in m^3 per hour
Single-flame				
1	1,5—3	0,3—0,7	2—3	0,6—1,4
2	1,5—3	0,6—1,1	2—3	1,2—2,2
3	1,5—3	0,9—2,1	2—3	1,8—4,2
Sieve				
4	1,5—3	1,2—2,5	2—3	2,4—5
5	1,5—3	1,6—3,4	3	3,2—6,8

As a result of wetting by the liquid combustible of the oxygen channels in an apparatus working on a kerosene-oxygen mixture, the occurence of "blow-backs" is possible, as a result of which flame penetrates into the oxygen channel of the burner and onward into the oxygen hose. This occasions bursting and burning of the hose and can lead to mishaps. To ensure safety during work with liquid combustible equipment one should insert into the oxygen line ahead of the burner a check valve of LKO-1-56 type.

When using a GKU burner it is necessary to observe the following rules: before lighting the burner one must warm up the evaporator to the point where evaporation of combustible starts.

Heating of the evaporator may be carried out by the following two methods.

1. Open completely the kerosene shut-off valve 12 (fig. 14), turn slightly counter-clockwise the knob for combustible feed control and pour into a special vessel (a sheet-iron can), filled with waste, a little of the combustible. Then light the kerosene in the vessel and warm up with it the evaporator and the head of the burner to the point where liquid combustible starts to evaporate.

2. The preparatory operations are the same, but the evaporator and the head of the burner warm up with a blowtorch or some other kind of outside heat source.

After warming the evaporator the knob of the valve must be turned all the way counter-clockwise and the knob for feed control of combustible must be given 3/4 of a turn or a full turn; then the vaporous mixture issuing from the mouthpiece must be lit. In this process the supply of combustible should be regulated by turning the knob located on the spindle of injector pipe.

With insufficient heating of the evaporator the mixture will at first burn with a smoky flame, since the combustible emerges in considerable part in the form of a liquid and, being evaporated outside the mouthpiece, creates a surplus of combustible in the flame.

In proportion as heating of the evaporator proceeds, there enters the flame an ever greater quantity of vapors and the surplus of combustible will decline to complete disappearance.

After complete heating of the evaporator normal flame is established by the knob for feed control of the combustible.

To shut off operation one must:

1) turn the kerosene cut-off valve all the way clockwise, and then the oxygen valve on the body of the burner; 2) remove pressure on the oxygen reducer, unscrewing to the point where the spring of the pressure screw of the reducer is freed, then opening the oxygen valve on the burner; 3) release the air from the tank for the combustible, opening the valve for dropping pressure; 4) after shutting down work the burner must be laid aside or suspended head-down, so that the combustible may not enter the oxygen line; 5) if the burner is turned off for a short time, then it must be placed above the weak flame of a blowtorch or above a flame of burning waste (as is described above), in such a manner that the evaporator is being kept warm all the time. In this way the burner will be in a state of readiness for work.

In the process of using the burner in single-shift work cleaning of the evaporator and the asbestos web must be carried out not less frequently than once a week.

If the web is severely clogged and burned, it should be replaced with a new one. To do this, wind onto the tube of the injector asbestos cord in the form of a spiral, the distance from the end of the injector to the web not to exceed 30 mm.

The web is secured on the injector tube with an iron or a brass wire of approximately 0.5 mm diameter.

Replacement of the web is a serious job, upon which the work of the burner depends. The web should be not too tight and not too loose

when it is put into the evaporator. In the first case it will pass an insufficient quantity of combustible for normal burning, in the second case the flame will rhythmically change in length due to leakage of combustible over the evaporator. The asbestos cord used for the web must not have textile or other combustible threads.

Cleaning of the holes of the mouthpiece is carried out with a "needle" of hard wood or a pure copper wire of proper diameter.

All valve seats of the burner are packed with asbestos cord, impregnated with liquid green soap.

When there is leakage of air in the pump one should inspect the pump cuff, and also the plug inserted in the valve of the pump, and replace them in event of their being worn out.

When there is failure to observe the necessary precautionary measures there occur blowbacks of flame, as a result of which the mouthpiece or the head of the burner may be melted, and sometimes the hoses may catch fire.

Blowbacks are caused by overheating of the head, obstruction of the outlets of the mouthpiece, insufficiency of combustible, weakening of adjustable nut and mouthpiece, obstruction of mixing chamber, and also entrance of kerosene into oxygen line.

To avoid blowbacks one should:

a) in event of prolonged uninterrupted work, periodically cool the head of the burner in water; in doing this the oxygen valve should be half-opened in order to prevent possible entrance of water into the head of the burner;

b) in event of obstruction of mouthpiece, turn it off and clean it;

c) periodically check tightening of mouthpiece and adjustable nut of mixing chamber, since they slack off in the process of work;

d) protect packing surfaces of mouthpieces and head from blows and scratches.

When there is a blowback of flame or an ignition of combustible in the hose one must immediately extinguish burner, closing (turning all the way to the right clockwise) the knob for combustible, and then the oxygen valve, and quickly close the valve for combustible on the tank.

One must not permit pressure in the fuel tank to be higher than the pressure of the oxygen, as shown by the manometer of the reducer,

since otherwise in a blowback the flame will go along the oxygen line and the oxygen hose can catch fire.

Gasoline-air burner

In brazing articles in metals and alloys having low melting points (lead, aluminum, magnesium, etc.), and also in brazing with low-melting-point solders gasoline-air burners are used (table 8).

Table 8

Technical characteristics of gasoline-air burner

Dimensions of mouthpiece or soldering bit	Air pressure in kg/cm^2	Consumption of air from compressor in liters per hr.	Consumption of combustible (gasoline) in grams per hour
Gas burner with tips having diameter of nozzle in mm:			
20	0.1-1.0	130-1800	20-400
30	0.1-1.5	140-2700	20-520
Gas soldering bit with weight of soldering prism in grams:			
240	0.1-0.5	130-1260	20-220
90	0.1-0.5	130-1260	20-220
40	0.1-0.2	130-270	20-40
30	0.1-0.2	130-270	20-40

In fig. 16 there is described a gasoline-air burner, put out by VNIIAVTO-GEN on the suggestion of V. A. Stepanov, which can also function as a gas soldering iron. Burner is furnished with two tips, but when functioning as a soldering iron, it is furnished with four soldering prisms.

According to the diagram (fig. 16, a), gas feed of the burner is carried out as follows. Air from the compressor passes through the local pressure regulator 1, and via the hose to the T-junction 2, of the gasoline tank 3. In the T-junction the air branches; one part proceeds directly into the burner 4, and the other into the tank of gasoline. In the tank there is an air admission tube fitted with a special valve. Air passes through this pipe, overcomes the resistance of the valve, then passes through a layer of gasoline, where it becomes saturated with vapors of the volatile fractions.

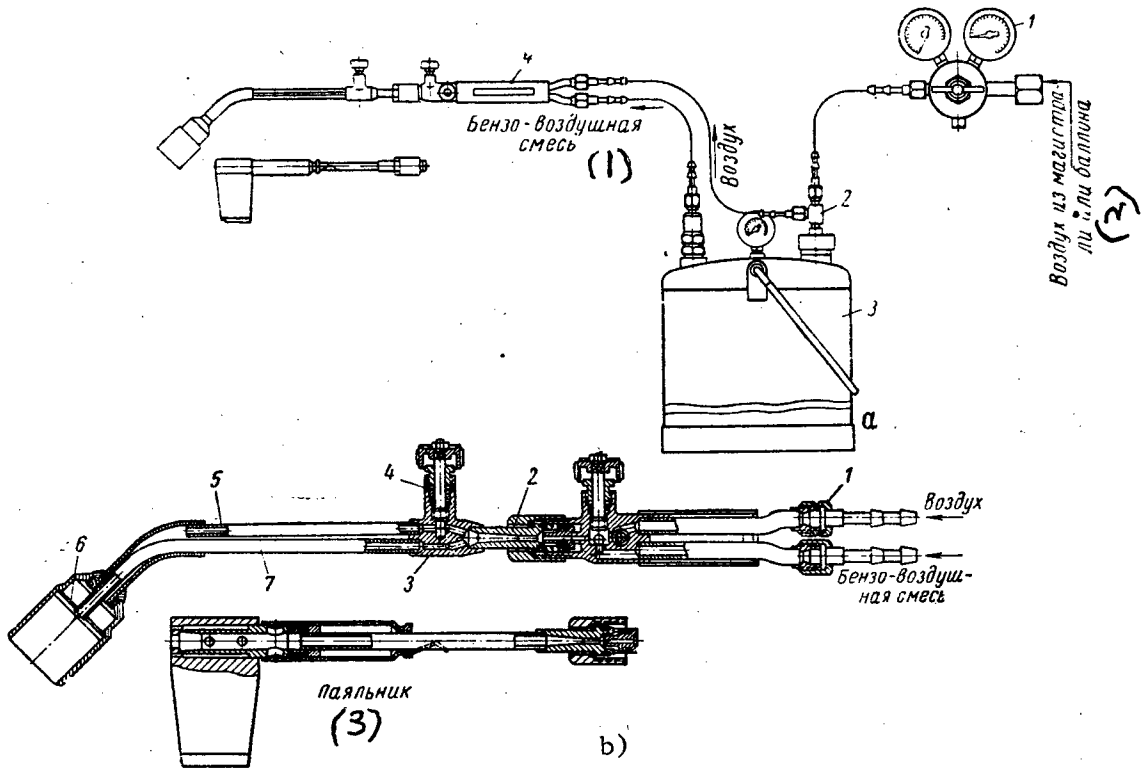


Fig. 16. Gasoline-air burner: a - diagram of gas feed; b - construction of burner.
1) gasoline-air mixture; 2) air from main line or container; 3) soldering iron

The gasoline-air mixture thus secured proceeds into the burner. In the burner (fig. 16, b) the air enters the mixing chamber 2 via the connection 1; there it is mixed with the gasoline-air mixture also entering here. The mixture diluted in this way passes into the body 3, where it again branches into two streams. One part of the mixture (via valve 4, tube 5 and grid 6 of the mouthpiece) enters the atmosphere and there burns, forming the main contour of the flame. The other part of the mixture passes via pipe 7 into the central opening of the mouthpiece, emerges into the atmosphere and burns, creating the core of the flame.

During use of the burner it is necessary to observe a number of rules. In igniting the burner one should open the gasoline-air mixture supply valve 1.4 turn, then light the mixture and set the flame normal with the air valve. With valve 4 (fig. 16, b) one can regulate the width of the flame (from 3 to 30 mm).

In the course of work the gasoline gradually becomes poor in light fractions. Therefore to maintain constant power of flame it is necessary to increase the quantity of air passing through the tank, to do which one gradually closes down the air valve to complete shut-off.

Steady and normal work of the burner continues until the moment of complete exhaustion of the light fractions of the gasoline. This takes place when approximately 50 % of the gasoline poured into the tank has been consumed. In this case the gasoline should be poured out and a new lot should be poured into the tank.

3. KGF-1-56 Apparatus For Automatic Supplying of Flux

In brazing with high-melting-point solders, mainly copper-zinc ones (see page 48), gas flux BM-1 (see page 63) is used. Its most effective application is in braze-welding of cast iron.

The vapors of flux BM-1 are put into the flame of the burner by the installation KGF-1-56. The installation set includes a flux feeder FGF-1-56 and a drying agent.

The flux feeder (fig. 17) consists of two steel reservoirs: the working tank 1 and the reserve tank 2.

In the cover 3 there is a valve mechanism which serves to distribute gas inside the flux feeder. It is separated from the reserve tank and is connected with working pipes 4 and 5.

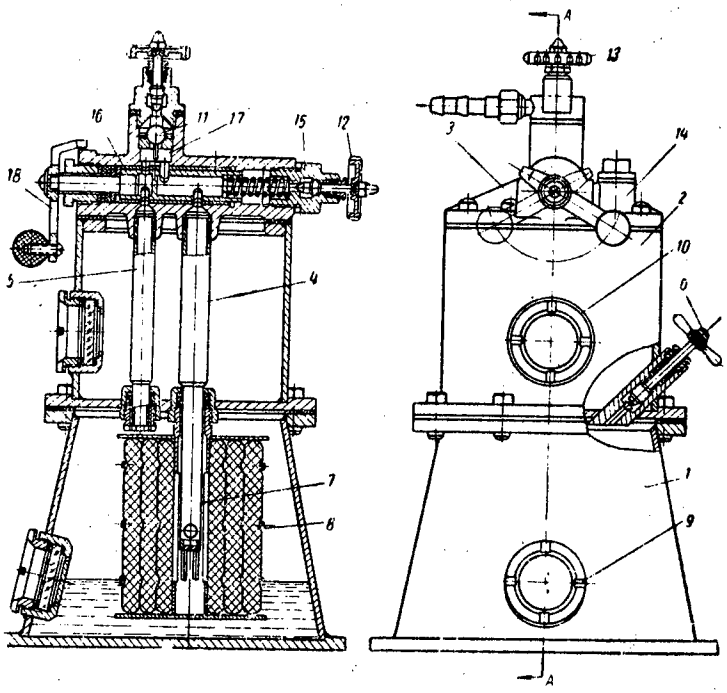


Fig. 17. Flux feeder FGF-1-56.

The reserve tank communicates with the working tank through drain valve 6. On pipe 4 there is put cage 7, on which wick 8 is reeled.

Both in the working tank and in the reserve tank there are provided inspection windows 9 and 10, which serve for checking the level of the fluxing liquid.

In output channel there is provided a check valve. In the check valve, the ball, 11, is depressed to the seat of the valve by gas pressure and flame does not pass into the flux feeder. Valves 12 and 13 at entrance and exit are shut-off valves, and serve to isolate the flux feeder from the environment.

The flux BM-1 is poured into the reserve tank through spout 14, and thence into the working tank upon opening of drain valve 6.

Acetylene from the feed source is conducted via hoses to the entrance connection 15 and passes into the valve tube 16. When the tube is in a position corresponding to division 0 on the scale of the flux feeder, none of the valve holes coincide with gas channels, and acetylene does not enter the burner. When the needle reaches division 1, a hole connecting tube 16 directly with output channel 17 is opened,

and acetylene not containing BM-1 flux will start to pass into the burner. With the needle at division 6 the holes connected with gas supply tubes 4 and 5 are fully open, and the hole leading into channel 17, is closed. Via tube 5 and through an opening in it acetylene passes through wick 8, impregnated with the fluxing liquid which has been poured into the working tank. Thereby the acetylene is saturated with flux vapors and is carried via tube 5 through channel 17 and its connection into the burner.

When the pointer of handle 18 is on divisions 2, 3, 4 and 5 the gas regulating holes occupy intermediate positions, and acetylene passes partially through the working space of the flux feeder, but in part directly into the burner. Thus consumption of flux is regulated by changing the amount of acetylene passed through the working space of the flux feeder.

Technical characteristics of flux feeder FGF-1-56

Outside dimensions in mm:	
diameter	410
height	260
Weight without flux, in kg	14
Capacity of working tank in liters of flux	2.4
Capacity of reserve tank in liters of flux	2.0
Required pressure of acetylene for operation of burner in mm, water column	Not lower than 50
Required pressure of oxygen in kg/cm^2	3.5--4.0
Capacity of flux feeder in liters per hour of acetylene (burner tips Nos. 0--7)	From 50 to 2,500
Consumption of flux in grams per cubic meter of acetylene passed through	70
One charging of flux feeder with liquid is sufficient for saturation with flux vapor of acetylene to the amount of (in m^3)	55

Table 9

Malfunctions in the operation of installation KGF-1-56, and methods for their removal.

Malfunctions	Cause of malfunctions	Methods of removal
Flame does not have sufficient color -- core visible during work at division 3	1) Prolonged work with badly dried gas -- flux has decomposed	1) Change charge of silica gel in dryer. Pour out flux and replace with a fresh lot
Flux is insufficiently active	2) Composition of flux does not correspond to specifications	2) Pour out flux and replace with a fresh lot
	3) Temperature in premises lower than + 10° C. Volatility of flux reduced	3) Move handle to divisions 4, 5, etc. until needed color of flame is secured. If at maximum division flux is still insufficient, place flux feeder in bath of warm water or of warm sand
	4) Work proceeds with little consumption of acetylene -- insufficient flux picked up	4) Move handle to divisions 4, etc. until needed color of flame is secured
Entrance of liquid into burner	Upon prolonged break in work flux feeder not freed from pressure of gas	Transfer handle into position 1, open acetylene valve on burner and blow out system with acetylene until liquid is eliminated from burner. Blow out only under local exhaustion of air when the burner is lit
Presence of white deposit at points of juncture, on flux feeder or on hoses;	Leakage of gas containing flux	

Table 9 continued

Malfunctions	Cause of malfunctions	Methods of removal
1) on valve seat nut of regulating flux handle		1) Change valve seat packing. Spindle is easily removed by unscrewing
2) on valves and points of juncture		2) Tighten valve seat nut of valve and adjustable nuts at points of juncture
3) on the flange of the water meter glass		3) Tighten flange with gas wrench
4) around the gasket between the working tank and the reserve tank		4) Tighten bolts, but if this is insufficient, change gasket
5) on the acetylene hose		5) Change hose
Spontaneous rising of the level of fluid in the working reservoir	Looseness of valve seat packing of the gas-bearing conduits in the bottom of the reserve tank	Take flux feeder apart and tighten valve seat nuts; if this is insufficient, change packing

As combustible gas in working with the apparatus KGF-1-56 one may use only acetylene. Feed of the burner with acetylene can be carried out either from a container, or from generators.

Acetylene from a container is comparatively free from moisture, while acetylene from a low or medium pressure generator contains a certain quantity of water. Moisture occasions the precipitation of a hard deposit - boric acid - in the flux feeder and in the gas communications, and also contributes to rapid impoverishment of the flux.

For this reason, in case acetylene from a generator is used, it is indispensable to connect up with the system a dryer in which the moisture is absorbed by silica gel.

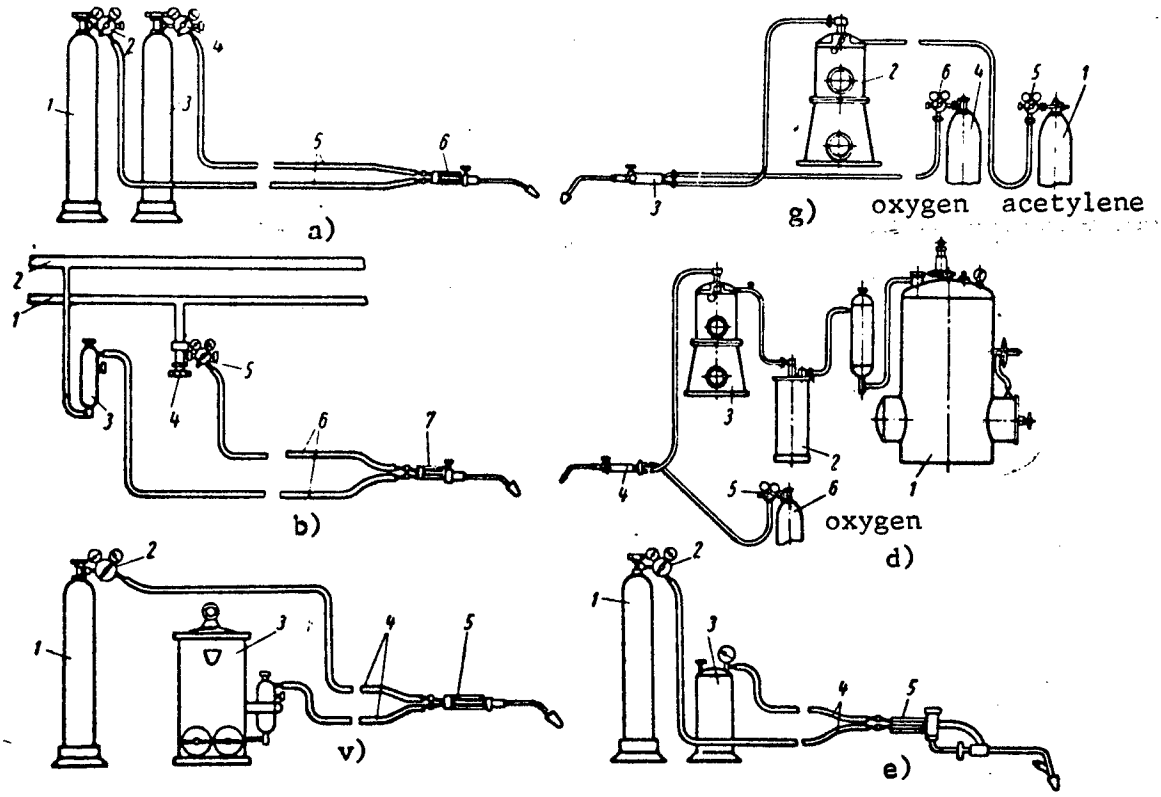


Figure 18. Diagram of a station in gas-flame brazing.

a. - diagram No. 1; 1. - oxygen cylinder; 2. - oxygen reducer; 3. - combustible gas cylinder; 4. combustible gas reducer; 5. - hoses; 6. - burners.

b. - diagram No. 2; 1. - oxygen tubing; 2. - combustible gas tubing; 3. - safety lock; 4. - oxygen station valve; 5. - oxygen reducer; 6. - hoses; 7. - burner.

v. - diagram No. 3; 1. - oxygen cylinder; 2. - oxygen reducer; 3. - generator; 4. - hoses; 5. - burner.

g. - diagram No. 4; 1. - acetylene cylinder; 2. - FGF flux feeder; 3. - welding burner; 4. - oxygen cylinder; 5. - acetylene reducer; 6. - oxygen reducer.

d. - diagram No. 5; 1. - acetylene generator; 2. - dryer; 3. - flux feeder FGF - 1 - 56; 4. - welding burner; 5. - reducer; 6. - oxygen cylinder.

e. - diagram No. 6; 1. - oxygen cylinder; 2. - oxygen reducer; 3. - kerosene tank; 4. - hoses; 5. - burner.

During work the level of fluid in the working reservoir must be visible in the inspection window. When there is insufficient fluid an insufficient quantity of flux will enter the flame. Exceeding the prescribed level creates the possibility of dripping of fluid into the flame of the burner, which is extremely undesirable.

For work with a fluxing flame the handle must be set at position 3. When this is done the flame should be of a bright green color and the core of the flame should be indistinguishable to the naked eye from the flare, which is an indicator of normal working on the part of the flux feeder.

When there is a brief interruption in the work it is sufficient merely to turn off the burner.

When there is a prolonged break in the work the pressure of gas in the flux feeder should be cut out. Otherwise when the apparatus is switched on again fluid may get into the hoses. For this reason it is necessary first to disconnect the feed source, to shift the handle of the flux feeder to position 6, to open the valve on the burner, and to release the gas into the atmosphere. Then one should shift the handle to position 0, close the valves on the flux feeder, and only thereafter close the valve on the burner.

It is necessary to check daily whether there is any leak of gas or flux from the flux feeder and its connections. Take-down and internal inspection of the flux feeder must be carried out monthly, when working from a generator, or every six months when working from cylinders.

It is recommended that inspection be carried out in the following order:

1) turn off bolts connecting the reserve tank with the working tank (drain valve of reserve tank must be closed); lift up reserve tank, squeeze flux from wick, remove wick, and set it aside in a sealed vessel;

2) remove all deposits in working tank by scraping, painstakingly wash it with hot water or steam, and dry it out; before assembly all components should be carefully dried; if on assembly it is observed that the wick is dry and hard, it must be replaced with a new one;

3) hook up the flux feeder and check all connections for airtightness.

Possible malfunctions in the work of the apparatus and the methods for their elimination are presented in table 9.

4. Diagrams of equipment at stations for gas-flame brazing

Depending on the composition of the gas mixture, the diagram of the equipment at a station for brazing changes.

When working with an acetylene-oxygen mixture the station may be equipped according to the diagrams 1, 2, 3 (Figure 18, a, b, v), and with supply of BM-1 flux, according to diagrams Nos. 4 and 5 (Figure 18, g, d).

Work with gas substitutes for acetylene in mixtures with oxygen is carried out with equipment at station according to diagram 1 or 2.

When working with liquid combustible (kerosene, gasoline), the brazing station should be set up according to diagram 6 (Figure 18, e).

IV. Materials Used In Brazing

1. Solders

Metals or alloys through the use of which the connection of solid metal bodies is carried out by brazing are called solders.

Solders are classified by the melting temperature and by the make-up of the metals on the basis of which they are created or which enter into their composition and determine their properties.

All solders used in brazing are divided according to melting temperature into two main groups: low-melting-point ones with a melting temperature below 400-450° (alloys on bases of tin, lead, cadmium, zinc, and bismuth), and high-melting-point ones with a melting temperature above 400-450° (alloys on copper, silver, gold, nickel, and magnesium bases).

The quality of the brazed joint and the productivity of brazing operations is determined to a considerable degree by the properties of the solder.

The basic requirements imposed upon solders are the following:

1) The melting temperature of the solder must be lower than the melting temperature of the metal to be brazed;

2) The solder must have certain physical properties: it must penetrate narrow gaps between surfaces to be brazed easily, it must ensure full wetting of surfaces to be brazed, etc.;

3) It is desirable that the solder should have approximately the same resistance to corrosion as the metals to be joined, or a little more;

4) For special cases, the electrical conductivity of the solder ought not to differ significantly from the electrical conductivity of the metals to be brazed;

5) The coefficient of heat expansion of the alloy and of the metal to be brazed should be as close as possible; the solder must not be hot-short, since otherwise stresses which appear in the process of brazing, would cause seams to crack;

6) In order to join two elements in metals of different characters it is best to select a sufficiently plastic and sufficiently ductile solder to withstand without breakage the stresses which arise in the process of brazing through the unequal heat expansion of the two elements;

7) For articles upon which there are imposed requirements as regards decorative qualities the solder must not be perceptibly distinguishable from the metals to be brazed in color;

8) The solder must be as cheap as possible and in as ample supply as possible.

The most important factor in selection of a type of solder is its melting temperature. The working temperature of brazing, i.e. the minimum heating temperature of the basic metal, at which there is ensured wetting, spreading, and filling of the gap by the solder, is ordinarily taken as being 20 - 100° higher than the temperature at which the solder becomes fully liquid. At the same time the operating temperature of brazing must be lower than the melting temperature of the metal to be brazed, by 30 - 50° as a minimum. In selecting solder it is also necessary to consider the conditions under which a brazed article will be used (mechanical loads, temperature, ambient, etc.)

Low-melting-point solders

Low-melting-point solders include the metals and alloys having low melting temperatures (up to 450°) and comparatively low hardness, for which reason these solders are also called soft solders.

Low-melting-point solders are used principally where high durability, airtightness, or electrical conductivity of the brazed joint is not required of the articles. Structures brazed with such solders can be used at comparatively low temperatures. Solders of this group moisten the surfaces of almost a majority of known metals well, something which makes it possible to use them for brazing very many metals and alloys.

In brazing with low-melting-point solders it is possible to avoid entirely warping and change in the mechanical properties of the metals to be brazed. Where they are used elements of decidedly complicated configuration, with large joined surfaces, are connected together by brazing, and also heavy-wall elements with thin-wall ones, without danger of burning the latter. Finally, through the use of brazing with these solders it is possible simultaneously to join many elements into a single nucleus. An example of such joining is the heat exchanger for an oxygen plant (figure 19).

Proper carrying out of the brazing operation leads in a majority of cases to the securing of reliably brazed joints with a good external appearance, not requiring subsequent machining.

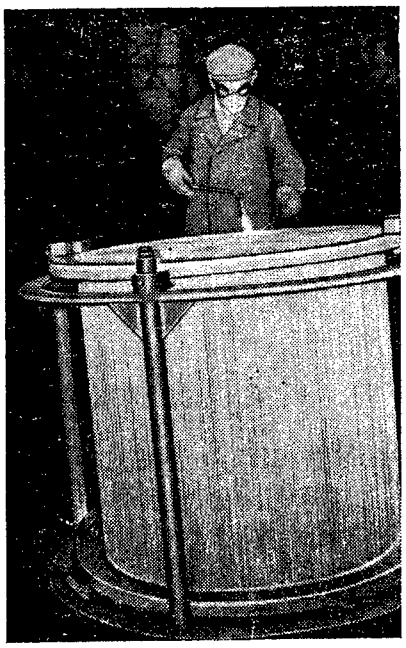


Figure 19. Condenser

The main solders of this group are basically made up of tin and lead. In addition, for brazing articles in aluminum and zinc alloys there are used solders on a zinc base, which are not dealt with in the present booklet, since they are not used in gas-flame brazing.

Tin-lead solders have been used for a very long time. There are data to the effect that at the very start of our era a tin-lead solder consisting of 30% tin, widely used even now, was already known at the start of our era.

The tin-lead solders melt over a range of temperatures from 183 to 277° C, in which connection the temperature of the beginning of melting for all solders is 183°, which is the melting point of an alloy of eutectic composition. The proportions of tin and lead in a solder determine its properties (table 10). The greater the tin content of the solder, the greater its resistance to corrosion and (within a certain range of concentrations) the lower its melting temperature. Lead is added to these alloys principally to reduce their cost.

To increase the strength of lead-tin solders from 1 to 6% of antimony is added to them. In alloys having a low tin content antimony lowers the melting temperature. At the same time, considerable additions of antimony may make the solder brittle.

Table 10

Chemical composition and properties of standard tin-lead solders

Brand of solder	Chemical composition in %			Temperature of complete melting, °C	Interval of crystallization, in °C	Tensile strength upon stretching, kg. per sq. mm
	Sn	Sb	Pb			
POS 90	89—90	0,15	Remainder	222	39	4,3
POS 61	59—61	0,8		183	7	—
POS 50	49—50	0,8		209	26	3,6
POS 40	39—40	1,5—2,0		235	52	3,2
POS 30	29—30	1,5—2,0		256	73	3,3
POS 18	17—18	2,0—2,5		277	94	2,8
POSS 4-6	3—4	5—6		265	20	5,8

To increase the strength of lead-tin solders from 1 to 6% of antimony is added to them. In alloys having a low tin content antimony lowers the melting temperature. At the same time, considerable additions of antimony may make the solder brittle.

The POS-61 solder, due to its low lead content, is the most corrosion-resistant and least toxic of all the solders in this group. Therefore it is used for brazing the internal seams of pots and medical equipment. The solder has the capability of joining the majority of steels, copper alloys, etc., well.

The POS-61 solder is the lowest melting point tin-lead alloy. It has the highest fluidity in a liquid state, and for this reason it is wise to use it only in cases where the surfaces to be joined have a tight fit with minimum gap and when great heating of elements to be brazed is inadmissible. In particular this solder is used in radio assembly work, the brazing of precision instruments, and in order to obtain especially tight-fitting joints. In all other cases, considering its being in short supply, one should use solders having a lower tin content.

POS 60 solder is used for brazing and tinning, for soldering joints which will be required to be vacuum-tight (for example in Dewar vessels), precision electrical gauging devices, radio apparatuses, aviation radiators, and the like.

POS 40 and POS 30 solders are most widespread in industry where there is need for sufficient tightness of seam, and high electrical and heat conductivity of the brazed joint. They are used in brazing air-fractionating and chemical apparatus, electric generators, instruments

coming into contact with sea water, and the like. POS 40 solder, as compared with POS 30, has higher fluidity and ensures more uniform seams of better quality.

POS 18 solder is the cheapest one of this group. It has a comparatively high melting temperature and is used for brazing articles of general consumption, automotive tractor components, and the like, in copper, brass, iron, and galvanized iron.

POSS 4-6 is used for brazing unimportant elements which do not go stress under load, or for the brazing of riveted and folded seams. Solder of this brand, and also POS 18 solder, have low plastic properties, which is explained by the increased antimony content.

The properties of brazed joints, depending upon the materials to be brazed, are set forth in table 11.

Solders on a lead base. As a result of the relatively high cost and the short-supply characteristics of tin, efforts are being made to devise solders without tin or with a low tin content. Such are lead solders with addition of silver and tin. Solders of this group are put out according to State Standard 8190-56 (table 12)

Table 11

Tensile strength of joints brazed with tin-lead solders
(in kg per square mm)

Solder	Material & character of joints								
	lap						butt		
	Brass	Copper	Iron	Zinc-plated iron	Galvanized iron	Brass-plated sheet	Brass	Copper	Iron
Tin	4,5	4,6	3,8	5,1	—	—	5,9	9,0	7,5
POS 40	4,6	3,7	6,1	4,7	4,8	4,9	8,0	7,8	10,0
POS 30	2,8	2,7	5,0	4,2	3,7	3,6	8,8	9,1	11,5
POS 18	3,3	5,1	3,1	4,3	3,8	4,6	9,7	9,0	10,5
POSS 4-6	3,0	2,4	4,9	2,6	—	—	7,7	—	—
Lead	2,0	1,9	1,4	1,7	—	—	2,6	3,6	7,9

Table 12

Chemical compositions of solders on lead base

Brand of Solder	Chemical composition in %				Melting temperature °C	
	Pb	Ag	Sn	Cd	Start	Completion
P Sr 3	96,0—98,0	3,3—2,7	—	—	300	305
P Sr 2,5	93,0—91,0	2,8—2,2	6,0—5,0	—	295	305
P Sr 2	64,5—61,5	2,3—1,7	31,0—29,0	5,5—4,5	225	235
P Sr 1,5	85,0—82,0	2,3—0,7	10,0—14,0	—	265	270

In their technological properties and above all in their wetting capability lead solders yield place to tin-lead ones and, as a rule, have a higher melting temperature. At the same time P Sr 3 and P Sr 2.5 solders surpass some tin-lead solders in mechanical strength properties. Furthermore, articles brazed with these solders can operate at higher temperatures (up to 200°), something that is exploited in electrical engineering.

Tin-lead solders are put out in the shape of ingots weighing 30-40 kg., pressed rods of 8 - 15 mm. diameter, wire of 0.5 - 0.5 mm diameter, or ribbon of 1 - 5 mm. thickness. Solder is also put out in the shape of tubes of 1 - 5 mm. diameter, filled with resin flux. In the last case soldering is done without preliminary fluxing of the seam.

High-melting-point solders

In cases where a high degree of strength, resistance to high temperatures, etc., are required from a brazed joint, high-melting-point solders are used. In brazing lap joints with these solders a joint of even strength [with the elements] is as a rule ensured.

Depending on their chemical composition, high-melting-point solders are classified in the following fashion:

1) copper and copper-zinc solders;
2) silver solders;
3) copper-phosphorus solders;
4) nickel solders;
5) gold solders;
6) aluminum solders;
7) magnesium solders.

The field of use of the solders of the various groups, depending on the metals to be brazed, is set forth in table 13.

Copper is practically not used in gas-flame brazing. The high melting temperature of copper makes it difficult to carry out the brazing process. Furthermore, the oxides present in it are easily reduced by hydrogen, with the formation of water vapor. The water vapors which are freed are not dissolved in the copper and are diffused from it only slightly, and since they are under very high pressure, they may lead to the formation of cracks in the seam.

Copper-zinc solders find very extensive use in industry, particularly in brazing copper and ferrous metals, since they have a relatively not very high alloy melting temperature which ranges, for the existing solders of this group, from 825 - 940° C.

With increase of the zinc content to 39% the plasticity and strength of the solder rises. At a content of more than 45 - 47% of zinc the alloy becomes brittle and weak.

Table 13

Field of use of the solders

Basic metal	Copper	Copper-zinc solders with additive				Silver solders with additives				Copper-phosphorus	Aluminum	Magnesium
		Cu—Zn	Cu—Zn—Si	Cu—Zn—Si—Sn	Cu—Zn—Ni—Si	Ag—Cu	Ag—Cu—Zn	Ag—Cu—Zn—P	Ag—Cu—Zn—Cd			
Copper.....	Н	Р	Р	Р	Д	Р	Р	Р	Р	Р	Н	Н
Copper alloys.....	Н	Д	Д	Д	Н	Д	Р	Р	Р	Р	Н	Н
Carbon and low-alloy steels.....	Д	Р	Д	Д	Д	Н	Р	Н	Р	Н	Н	Н
Cast iron.....	Н	Р	Д	Д	Р	Н	Р	Н	Р	Н	Н	Н
Rust-resistant & heat resis. steels & alloy	Н	Д	Д	Д	Н	Н	Р	Н	Р	Н	Н	Н
Alum. & its alloys..	Н	Н	Н	Н	Н	Н	Н	Н	Н	Н	Р	Н
Magnesium & alloys..	Н	Н	Н	Н	Н	Н	Н	Н	Н	Н	Н	Р

Note: N - not admissible; R - recommended; D - admissible, but with limitations. /Н = N; Р = R; Д = D/

The main difficulties in brazing with these solders are associated with the ready volatility of one of the components of the alloy - zinc.

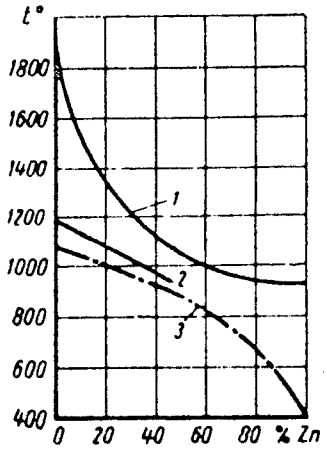


Figure 20. Dependence of the boiling temperature of zinc upon its content in a copper-zinc alloy:
1 - Boiling temperature of zinc;
2 - Brazing temperature;
3 - Melting temperature of the alloy.

Pure zinc boils at a temperature of 906° C; in an alloy the boiling temperature of the zinc rises and depends upon its percentage content in the alloy, (figure 20). As a result of the evaporation of the zinc the qualities of the brazed joint deteriorate. As the zinc evaporates the solder becomes harder to melt and less fluid, and consequently it fills up the gap between the elements to be brazed less well. Besides, up to a certain limit the mechanical qualities of the brazed joint deteriorate. If a bath of the liquid solder is surrounded by gases soluble in it, then as a result of the boiling of the zinc the porosity of the seam will be increased. Furthermore, tin oxide which forms in the atmosphere is harmful for the health of the brazer. Its presence in the atmosphere to the extent of more than 0.005 milligrams per liter causes illness.

Combatting the evaporation of zinc is done by introducing into the composition of the solders or the fluxes silicon, aluminum, or boron. In order to reduce zinc evaporation an oxidizing flame is also used.

In domestic industry there are also used special copper-zinc solders, and also some brands of brass.

The solders shown in table 14 are the lowest melting-point ones of the copper-zinc solders, but as a consequence of their high zinc content they are not suitable for brazing of articles working under alternating impact and bending loads.

Solders of this group are most frequently used in the form of grains of 0.2 to 5.0 mm. size.

PMTs 36 solder has low mechanical properties; therefore it is used extremely rarely, for example in brazing articles of L 62 brass which do not have to bear stress.

Table 14

Compositions and properties of copper-zinc solders

Brand of Solder	Chemical compositions %		Impurities %, not more than		Temp. of comp. melting in °C	Tensile strength in kg/mm²	Expansion in %
	Cu	Zn	Pb	Fe			
PMTs36	34—38	Remainder	0,5	0,1	825	3	0—1
PMTs48	46—50		0,5	0,1	865	21	3
PMTs54	52—56		0,5	0,1	880	25	5

Table 15

Compositions of brasses used as solders

Brand	State Standard or specifications	Chemical compositions in %					Impurities % not more than		Melting temperature °C
		Cu	Sn	Si	Ni	Zn	Pb	Fe	
Л68	1019-47	67,0—70,0	—	—	—	Remainder	0,03	0,1	938
Л62	1019-47	60,5—63,5	—	—	—	Ditto	0,1	0,2	905
ЛК 62-05	TUTsMO 1327-54	60,5—63,5	—	0,3—0,7	—	»	0,1	0,2	905
LOK 62-06-04	TU VNIIAVTOGEN	60—63	0,4—0,6	0,3—0,4	—	»	0,1	0,2	905
ЛОК 59-1-03	TUTsMO 1331-54	58—60	0,7—1,1	0,2—0,4	—	»	0,1	0,2	890
LOK 56-03-6	TU VNIIAVTOGEN	55—57,5	—	0,25—0,3	5,5—6,0	»	0,1	0,2	905

[Л - L]

PMTs 48 solder is used for brazing articles in copper alloys which do not work under impact or alternating loads and which have melting temperatures above 900-920° C.

PMTs 54 solder is used also for articles which are not subjected to impact, bending, or alternating stresses and which are of copper, steel, and the like.

Brazed joints made with some of the industrial brass alloys have considerably better mechanical properties (table 15).

Brasses are used for brazing copper, steel, nickel, and cast iron. Brazed joints made by gas-flame brazing with these solders have great strength, and good resistance to impact and bending. On account of the evaporation of zinc brasses are not recommended for brazing connections which operate in a vacuum.

Table 16

Physical-mechanical properties of copper-zinc solders

Brand of Solder	Specific gravity in grams per sq. cubic centimeter	Coefficient of linear expansion X 10^6 in mm per meter X degrees	Specific elec. resistance in ohms X mm^2 per meter	Mechanical properties of soldered joints		
				Tensile strength under stretching kg per sq. mm	Resistance to shear	Angle of bend, in degrees
PMTs 36	7,7	22	0,03	—	—	—
PMTs 48	8,2	21	0,036	27,8—34,0 / 31,3	18,0—25,0 / 20,9	5—25 / 12
PMTs 54	8,3	21	0,04	—	—	—
L 62	8,5	20	0,071	40,6—44,8 / 43,0	25,0—33,3 / 27,5	30—102 / 63
LOK 62-06-04	—	—	—	41,0—45,6 / 43,8	30,2—33,4 / 31,6	62—86 / 72,5

Note: In the denominator there are given the mean figures for the results of 5-7 samples, in the numerator the minimum and maximum figures.

Solders L 68 and L 62 are used for brazing copper and steel. Seams filled with these are as a rule tight and sufficiently strong (table 16). But in machining such joints, for example under a galvanized covering, pores often open up, which is an indirect consequence of the evaporation of zinc. This defect is eliminated by using BM-1 flux (see page 65).

Brass LK 62-05 is recommended as a solder for braze-welding of cast iron. This alloy of L 62 brass is distinguished by the presence of only 0.5% silicon. As a result of the last, in braze-welding there is a practical absence of zinc evaporation. The protective action of the silicon is explained by the formation of silicon slags on the surface of the liquid metal, impenetrable for the zinc vapors, or by increased surface tension of the liquid metal.

The metal of the seam is in this event solid, with high strength indices. At the same time, in braze-welding with this solder there takes shape at the border of the alloying with ferrous metals a brittle layer (figure 21) consisting of siliceous ferrite having a silicon content of about 12%, as a result of which a solid bonding is not ensured. In order to increase the strength of the bonding of the brass with the base metal it is recommended that the first, servicing, layer be filled out with plain brass of brand L 62.

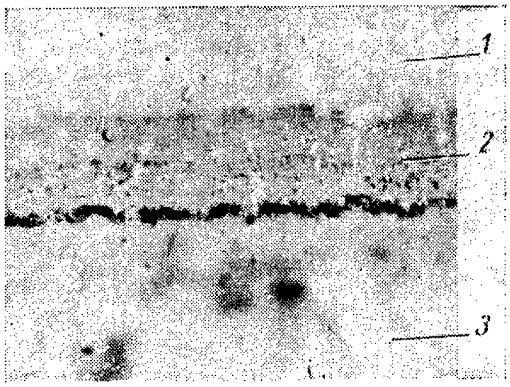


Figure 21. Structure of brazed sample at the border of the alloying of brass with cast iron (X 500)
1 - LK 62-05 brass; 2 - brittle; 3 - cast iron

LK 62-05 brass is not recommended for capillary brazing, since in consequence of the presence of viscous slags the solder does not flow and fill the gaps well enough.

Brasses LOK 62 and LOK 59, among all the solders of this group, have the highest technological properties.

The silicon present in their composition does not permit the evaporation of zinc. The tin somewhat lowers the temperature of melting and increases fluidity. The solders flow into gaps well and ensure high strength and tightness of seam, for which reason they are recommended for capillary brazing and also for braze-welding, in the latter case with the same limitations as for LK 62-05.

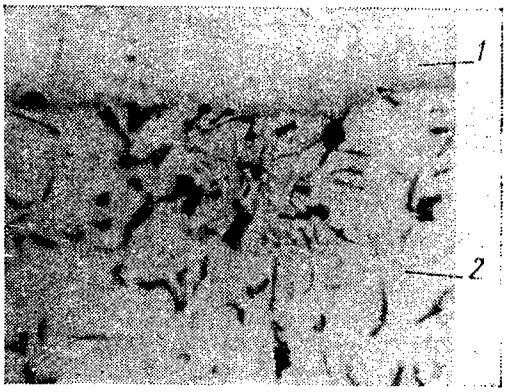


Figure 22. Structure of brazed sample at the border of alloying of brass with cast iron (X 200).
1 - brass LKN 56-03-6; 2 - cast iron

In capillary brazing the formation of a brittle layer at the border of the alloying of the LOK solders with the ferrous metals is also possible. But the volume of the liquid solder and the time of its contact with the basic metal are slight, for which reason the brittle layer is of insignificant thickness and trifling influence upon mechanical properties.

LKN solder is recommended for braze-welding of cast iron. It belongs in the category of the "smokeless" high-strength brasses. The presence in it of nickel ensures, in contradistinction to the purely silicon brasses (for example LK 62-05), the absence of a brittle layer at the border of the alloying with the cast iron (figure 22). In color the alloy is pretty close to cast iron.

Silver solders are used for brazing all ferrous and non-ferrous metals, with the exception of aluminum, magnesium, and other metals which have a very low melting point. Despite the fact that silver is in short supply, the solders of this group find widespread use both in machine building and in instrument making.

The silver solders have high technological properties: they flow well, they wet the surface and fill the gap between the surfaces to be brazed. The relatively low melting temperature of some brands of solders in this group permits their use for brazing heat-treated parts, metals of differing sorts, etc.

The brazed joints made with such solders are of great strength, good plasticity and working qualities, and also high corrosion resistance in various milieux. In addition, the relatively high cost of these solders is partially made up for by the cutting of the heating time in working with them.

The nomenclature of silver solders is extraordinarily extensive. Into their composition there enters, in addition to silver, also copper, zinc, and in recent years cadmium, phosphorus, manganese, and other metals have commenced to be added.

The melting temperature, the mechanical properties, and the color of the solders depend upon the content of each of the basic components.

The most widely used solders of this group are put out according to State Standard 8190-56. In accordance with this State Standard four groups of high-melting-point solders are put out (table 17).

The first group includes binary alloys of silver and copper, having the highest electrical conductivity, for which reason they are used for elements which carry current.

The second group of solders has general purposes. PSr 70 is used for brazing connections in copper and its alloys, and in certain precious metals. The solder has high electrical conductivity, for which reason it is used for elements which carry current. Brazed joints made with it have high ductility and resistance to corrosion.

PSr 50 also has low electrical resistance and is used where this property must be combined with high heating. Solders PSr 25 and 45 have the widest application. They are used to braze steel, copper, and its alloys; they provide high mechanical properties of joint. PSr 45 solder has higher mechanical properties (table 18) and provides tighter seams.

The third group of solders, containing phosphorus, has a comparatively limited range of use. Phosphorus, which lowers the melting temperature of the alloy, at the same time increases its brittleness, for which reason such solders are not recommended for joints working under impact, alternating, or bending loads. They are also not recommended for brazing ferrous metals, since at the border of melting brittle iron phosphides form, and the joint is ill suited for use.

Table 17

Composition and properties of silver solders (State Standard 819056)

Group	Brand of solder	Chemical composition in percentages							Impurities, %, not more than	Melting temperature in degrees Centigrade	Specific gravity, grams per cubic centimeter	Specific elec. resistance in ohms X mm^2 per meter
		Ag	Cu	Zn	P	Cd	Mn	Ni				
I	ПСр72	72±0,5	$28^{+0.5}_{-0.7}$	—	—	—	—	—	0,25	779	9,9	0,022
	ПСр50	50±0,5	$50^{+0.5}_{-0.7}$	—	—	—	—	—	0,25	850	9,3	0,025
II	ПСр70	70±0,5	26±0,5	4±1,0	—	—	—	—	0,5	755	9,8	0,042
	ПСр65	65±0,5	20±0,5	$15^{+1.0}_{-1.5}$	—	—	—	—	0,5	—	—	—
	ПСр45	45±0,5	30±0,5	$25^{+1.0}_{-1.5}$	—	—	—	—	0,5	725	9,1	0,097
	ПСр25	25±0,3	40±1,0	$36^{+1.5}_{-2.0}$	—	—	—	—	0,5	775	8,7	0,069
	ПСр12М	12±0,3	52±1,0	$36^{+1.5}_{-2.0}$	—	—	—	—	0,5	825	8,5	0,076
	ПСр10	10±0,3	53±1,0	$37^{+1.5}_{-2.0}$	—	—	—	—	0,5	850	8,45	0,065
III	ПСр71	71±0,5	$28^{+0.7}_{-1.0}$	—	1±0,2	—	—	—	0,3	795	9,8	0,04
	ПСр25F	25±0,5	70±1,0	—	5±0,5	—	—	—	0,5	710	8,5	0,18
	ПСр15	15±0,5	80,2±1,0	—	$4,8^{+0.2}_{-0.3}$	—	—	—	0,5	810	8,3	0,22
IV	ПСр50кд	50±0,5	16±1,0	16±2,0	—	18±1,0	—	—	0,5	650	9,3	0,72
	ПСр44	44±1,0	27±1,0	16±2,0	—	8±1,0	3±0,5	2±0,5	0,5	800	8,9	0,19
	ПСр40	40±1,0	$16,7^{+0.7}_{-0.3}$	$17^{+0.8}_{-0.4}$	—	$26^{+0.5}_{-1.0}$	—	0,3±0,2	0,5	605	8,4	—
	ПСр37,5	37,5±0,5	48,8±1,0	5,5±0,5	—	—	8,2±0,3	—	0,5	810	8,9	0,31

$[\Pi C_p = PSr]$

Table 18

Mechanical properties of brazed joints in L62 brass

Brand of Solder	Tensile strength upon fracture in kg per sq millimeter at temperature of ___ degrees Centigrade			Tensile strength upon shearing, in kg per sq millimeter at temperature of ___ degrees Centigrade			Impact ductility in kg per square millimeter	Angle of bend in degrees
	20	200	-193	20	200	-193		
PSr 45	35.0	32.6	44.5	21.2	17.2	30.0	6.4	180
PSr 25	29.8	30.7	35.3	23.7	17.9	25.8	2.8	63
PSr 15	--	--	--	--	--	--	0.23	36

The solders of this group have high fluidity, penetrate well into narrow gaps, and give tight seams. Thanks to the high fluidity of the alloys the working temperature of brazing is somewhat lower, in their case, than the temperature of complete melting.

Thus, for example, solder PSr 15 with a melting temperature of 810° C has an operating temperature of brazing in the range 730-848°.

Thus brazing with phosphorus solders can take place under circumstances where they are in a solid-liquid state. Experiment has shown that the normal flow of the solder into the gap takes place when there is no less than 70% of the liquid phase. The presence of the hard medium is revealed upon the carrying out of technological tests on spreading (table 19). As may be seen from the data presented, even under circumstances of incomplete melting PSr 15 solder has higher technological properties than PSr 45 or PSr 25.

Copper-phosphorus solders containing silver are self-fluxing; i.e., a flux does not have to be used. In brazing the solders take on a light gray color. After pickling in a solution of 10% sulphuric acid they again take on the color of copper.

Solders of the fourth group have special uses. Cadmium solders (PSr 40, PSr 50 kd) are the lowest melting point ones and are used for articles which do not admit of overheating.

Table 19
Technological properties of silver solders

Brand of solder	Test temperature in degrees Centigrade	Brand of flux	Spreading capacity in sq centimeters**	Height of capillary rise, in mm***
PSr 45	800±20	209	5	54
PSr 25	840±20	Borax	5	40
PSr 15	660±20	209	10*	70

*Melting incomplete.
**Test on brass plate, weight of solder 140 mg. and of flux 1 mg.
***Determined on a brass spiral (length 40 mm., wire of 1.3 mm. diameter).

Silver solders are put out in the shape of sheets, wires, and foils.

In recent years copper-phosphorus solders have found considerable application in brazing copper and its alloys, especially in the electrical industry.

In a whole series of cases they appear as substitutes for some silver and low-melting-point solders. The virtue of these solders is their low cost. At the same time they have a comparatively low melting temperature, have good technological properties, and in electrical conductivity they approach copper. A brazed joint made with copper-phosphorus solders can compete in shearing strength with joints made with PSr 45 type solders. The main defect of these solders is their brittleness, for which reason they cannot be used for parts which are subjected to blows, vibrations, or bending loads, or for brazing ferrous metals and alloys.

The brazing of copper with these solders can be carried out without flux, but in other cases the use of flux is indispensable. The most frequently used solders of this group are described in table 20. The solders are used in the form of cast rods, roller strips, and shavings.

Aluminum solders. Aluminum and its alloys are brazed with the aid of gas-flame heating only with high-melting-point solders. In domestic practice the most widespread use has been achieved, in the capacity of such a solder, by a triple alloy on a basis of aluminum with additives of copper and of brand 34A silicon.

Table 20

Chemical composition and properties of copper-phosphorus solders

Brand of Solder	Chemical composition in %				Impurities, %, not more than	Melting temp. °Centigrade	Stretch strength of brazed seam, in kg. per square mm		Bending angle in degrees
	P	Zn	Sn	Cu			Copper	Brass L62	
PMF 7	7,0	—	—	Remainder	0,1	850—860	12,6	14,6	10,7
PMF 9	9	—	—		0,1	780	12	13,2	7,6
PFOTs 7-3-2	6,0—7,0	1,0—3,0	2,5—3,5		0,1	680—700	15—19	17—21	—

The use of aluminum and its alloys for complicated parts has brought on a need to extend the list of solders. There has arisen a requirement for special brazing, in which there is required the presence of some solders having differing melting temperatures.

In connection with the use of aluminum for electrotechnical ends there has arisen the need for brazing it with copper, which has also called for the devising of special solders. The most widespread solders of this group are presented in table 21, and the field of their use in table 22.

Table 21

Composition and properties of solders for brazing aluminum

Brand of solder	Chemical composition %					Temperature in °C
	Al	Cu	Si	Zn	Cd	
П590А	89	10	1	—	—	590
П575А	80	—	—	20	—	575
34А	66	28	6	—	—	525
П425А	20	15	—	65	—	425
П300А	—	—	—	60	40	300
Eutectic Silumin	88,3	—	11,7	—	—	577

Table 22

Selection of solders and fluxes for brazing aluminum and its alloys

No. of group	Brand of the basic material joined by brazing	Brand of Solder	Brand of flux
1	Aluminum and its alloys AMts, AMg, and AMk	П590А, П575А, 34А, П425А, П300А	34А, 17, Ф380А, Ф370А
2	Alloys D1, D16, D20, V95, AL2, AL9, and AL11, joined by brazing with each other and with materials of the first group	П425А, П300А	34А, 17, Ф380А, Ф370А
3	Copper and its alloys with aluminum and its alloys	П300А	Ф370А, Ф220А

Magnesium solders, magnesium alloys, like aluminum ones, melt at comparatively low temperatures on the order of 600° Centigrade, for which reason standard high-melting-point solders cannot be used for them. In brazing magnesium and its alloys only alloys on a basis of magnesium-aluminum ensure satisfactory mechanical properties and corrosion resistance in the brazed joint.

The composition of the magnesium solders recommended for brazing and the fields of their use are presented in table 23.

Table 23
Compositions of magnesium solders, their compositions, and their purposes

Brand of solder	Melting temperature in °Centigrade	Tensile strength in kg per sq. millimeter	Chemical composition %			Field of use
			Al	Zn	Mg	
P380Mg	380	10-12	2.0-2.5	23-25	Remainder	For brazing alloys of the following brands: MA1, MA2, MA3, MA5, MA8, MG, ML5
P430Mg	430	13-15	0.75-1.0	13-15		For brazing alloys of the following brands: MA1, MA2, MA8, MG

2. Fluxes

Fluxes is the name given to substances which are spread upon the surface of the metal during brazing in order to facilitate the alloying of the solder with the basic metal. A flux must remove the oxide film from the surface of the metal, protect it from oxidation in the heating process, improve the wetting with liquid solder of the surface of the metals to be brazed, and ensure the flowing of the solder into the gaps between the elements to be joined.

In the selection of a flux composition the following basic requirements are imposed upon it:

1) The melting temperature of the flux must be lower than the melting temperature of the solder; its boiling point must be higher than the boiling point of the solder, in order to avoid evaporation of flux in the brazing process;

2) The flux must actively reduce oxides or combine them by converting them into chemical compounds having a lower melting point, or eliminate them through physical decomposition;

3) The flux must have the lowest possible specific gravity, so that it will float on the surface and not remain in the metal of the seam;

4) The elimination of traces of flux and the slag formed by it upon cooling of the place of brazing must take place through simple means.

Fluxes are applied in the form of powder, paste, and readily volatile liquids.

In gas-flame brazing as a rule flux has to be used. It is only in brazing copper with solders containing phosphorus that one can get along without flux, but even in this case its use improves the quality of the brazed joint.

Fluxes for brazing with low-melting-point solders

Fluxes for brazing with low-melting-point solders may be broken down into two main groups:

1. Fluxes having a high degree of activity, but provoking corrosion of brazed joints if the remnants thereof are not removed from the point of brazing.

2. Fluxes which are less active, but the remains of which upon a brazed surface do not give rise to, or give rise only to insignificant, local corrosion.

In brazing with the heat of a burner, i.e. with an open flame, only fluxes of the first group are used.

Fluxes of the first group which are chemically active or which are acid have the widest distribution and can be used for brazing the majority of metals and alloys (table 24).

The most widespread as a flux is zinc chloride (ZnCl); it enters into the composition of many complicated fluxes (fluxes 1 to 6). Its widespread distribution is to be explained by its high activity with respect to the oxides of the majority of ferrous and non-ferrous metals.

Zinc chloride is a white powder which readily takes up moisture from the air. It is used in the form of a water solution. It can be obtained by pickling with hydrochloric acid, for which purpose there are put into the latter small pieces of zinc until the reaction entirely stops. Brazing with zinc chloride is done at a temperature above 263° Centigrade.

Increasing the activity of a flux of zinc chloride is achieved by adding to it a little ammonium chloride (fluxes 2, 5). Ammonium chloride (NH_4Cl), or, as it is called, nashatyr [sal ammoniac], consists of a white crystalline powder. Upon being heated it enters into a chemical

Table 24

Compositions and fields of application of chemically active fluxes

Number of flux	Component parts of flux	Contents, % by weight	Copper to copper, Copper to brass	Brass to brass	Bronze to bronze, bronze to copper, bronze to brass	Zinc to zinc	Zinc alloy, con. 2% of aluminum (casting under pressure)	Carbon steel to carbon steel	Rust-resistant steel to rust-resistant steel	Cast iron to cast iron	Carbon steel to brass, to copper
1	Zinc chloride.....	48	+	+	+	—	—	+	—	—	+
	Water.....	52									
2	Zinc chloride.....	48									
	Ammonium chloride...	12									
	Water.....	40	+	+	+	+	—	+	—	—	+
3	Zinc chloride.....	48									
	Hydrochloric acid (specif. gravity 1.19)	10	+	+	+	—	—	+	—	—	+
	Water.....	42									
4	Zinc chloride.....	42									
	Hydrochloric acid (sp. gr. 1.19).....	22	—	—	—	—	—	—	+	—	—
	Water.....	36									
5	Zinc chloride.....	35									
	Ammonium chloride...	20									
	Hydrochloric acid (sp. gr. 1.19).....	40	—	—	—	—	—	—	—	+	—
	Water.....	5									
6	Zincchloride.....	60									
	Water.....	40	—	—	—	+	—	—	—	—	—
7	Orthophosphoric acid (sp. gr. 1.7).....	40									
	Water.....	60	+	+	+	—	—	+	—	—	+
8	Orthophosphoric acid (sp. gr. 1.7).....	100	+	+	+	—	—	+	—	—	+
9	Caustic soda.....	100	—	—	—	+	—	—	—	—	—
10	Hydrochloric acid (sp. gr. 1.19).....	100	—	—	—	+	—	—	—	—	—

Note: The plus sign means that the flux in question is recommended for brazing the materials indicated, the minus sign that the flux is not recommended.

reaction with oxides of metals (MeO); the interaction may take place according to two reactions:

$$4MeO + 2NH_4Cl = 3Me + MeCl_2 + N_2 + 4H_2O;$$
$$MeO + 2NH_4Cl = MeCl_2 + H_2O + 2NH_3.$$

Under the first reaction metal is restored from the oxide. The water vapors, metal chlorides, and nitrogen which arise from this are easily eliminated. According to the section reaction all the substances which form are gaseous, for which reason the surface of the seam is easily cleansed of them. This is the way fluxing goes in the brazing of iron, aluminum, etc.

In cases where there is need for an even more active flux, for example in the brazing of rust-resistant steels and alloys, there is added to the zinc chloride hydrochloric acid (fluxes 3, 4, and 5). In brazing rust-resistant steels the best results are given by flux 4. There is a theory that in the process of brazing rust-resistant steel the hydrochloric acid in the flux dissolves the oxide film and partially also the metal, and the zinc covers the surface of the metal which has been cleansed of oxides with a delicate film, preserving it from further oxidations.

The remnants of fluxes 3, 4, 7, and 8, which contain hydrochloric and orthophosphoric acids, exhibit a strongly corrosive action upon the brazed joint in carbon and rust-resistant steel. For this reason after brazing the article must be carefully washed.

Washing is also obligatory after brazing with the use of less active fluxes.

If for one reason or another it is difficult to wash the article, the use of fluxes of the second group is recommended; but in this case heating during brazing must be done by a soldering iron, because the organic substances in these fluxes catch fire in an open flame.

Fluxes for brazing with high-melting-point solders

In high-temperature brazing such substances as zinc chloride, sal ammoniac, etc., cannot be used, since under these circumstances they completely lose their fluxing properties. In the selection of a flux for brazing with high-melting-point solders it is indispensable to take into account not only the temperature at which the latter melt, but also the character of the oxides which form on the surface of the parts to be brazed.

In cases where there form on the surfaces of the metal to be brazed oxides which are chemical bases (CuO, Fe_2O_3, ZnO, etc), substances of an acid character are put into the flux, and vice versa.

The interaction of these substances with the oxides takes place with the formation of easily fusible salts, according to the reaction

chemical base plus acid = salt.

As acid fluxes there are used for the most part boric acid (H_3BO_3), borax ($Na_2B_4O_7$), boric oxid (B_2O_3), and some other salts.

In brazing alloys containing oxides of an acid character (silicon dioxide SiO_2 in the brazing of cast iron) basic salts, such as for example Na_2CO_3, are put into the flux.

The most widespread substances used in fluxes, and their properties, are set forth in table 25.

Table 25

Properties of substances used in fluxes

Components of fluxes	Temperature °C		Heat of formation, in kilocalories per gram-molecule	Specific gravity, in grams per cubic centimeter
	Melting	Boiling		
B_2O_3	577	—	282	1,8
$Na_2B_4O_7 \cdot 10H_2O$	741	—	—	—
LiF	842	1676	144,7	2,6
KF	846	1505	134	2,4
NaF	988	1695	136	2,7
CaF_2	1375	—	289	3,16
LiCl	606	1382	98	2,1
KCl	768	1417	105,8	2,8
NaCl	800	1439	97,9	2,2
$CaCl_2$	775	—	191	2,15

Fluxes for high-melting-point solders are divided into two main groups: 1) fluxes used over a temperature range from 850 to 1100 degrees Centigrade; 2) fluxes used at a brazing temperature of 600-850° Centigrade.

The first group of fluxes (table 26) is used in brazing with copper-zinc solders and some of the higher-melting-point silver solders.

Table 26

Composition of fluxes for brazing with high-melting-point solders

Brand of flux	Chemical composition	Field of use	Brazing temperature in °Centigrade
1	Borax ($Na_2B_4O_7 \cdot H_2O$) - 100%	Brazing copper and its alloys, carbon steels, etc.	over 800
BM-1	Methyl borate $[B(OCH_3)_3]$ - 70-75% Methyl alcohol (CH_3OH) -- remainder		
200	Boric acid (H_3BO_3)- 70% ± 2 Borax ($Na_2B_4O_7$)-21% ± 2 Calcium fluoride (CaF_2) - 9% ± 1	Brazing of rust-resistant and heat-resistant steels and alloys	above 900
201	Boric acid (H_3BO_3) - 80% ± 1 Borax ($Na_2B_4O_7$) - 14% ± 1 Calcium fluoride (CaF_2) - 5.5% ± 0.5 Bonder (Al-Cu-Mg) - 0.5% ± 0.1		

A widespread flux in this group is borax ($Na_2B_4O_7 \cdot 10H_2O$). Upon being heated borax loses the water of crystallization, which is accompanied by vigorous boiling. In order to avoid this in brazing, it is necessary to heat it in advance to a temperature of 400-450°. The melting temperature of borax is 741° Centigrade, but its active functioning commences starting from 800° C; at lower temperatures it flows badly. Borax together with oxides forms relatively fusible borates, in which process the slags that form rise to the surface of the brazed seam in the form of a hard glassy crust, barely soluble in water and very difficult to clean off mechanically, which constitutes a defect of this flux.

A less active flux is boric acid (H_3BO_3). Upon being heated it decomposes, with the formation of water and of boric oxide B_2O_3. The latter forms with oxides of copper, zinc, iron, and nickel relatively easily soluble borates and other compounds. The melting temperature of boric oxide is 577° C, but its relatively active functioning starts from 900° C and up.

Most frequently boric acid is used in mixture with borax and other salts.

Within the same group there falls the flux BM-1 (VTUP-4-58) of the Ufimski chemical plant), which, in contradistinction to the foregoing powder-form fluxes, consists of a readily evaporating liquid. The boiling temperature of this liquid is 54-56° C. The vapors of the flux, with the assistance of the KGF-1-56 apparatus (see page 34) are conveyed by acetylene in a certain quantity into the flame of the burner, where they burn with the formation of boric oxide vapors (B_2O_3). The vapor form thereof, active (at the moment of being formed), ensures an incomparably more effective fluxing than boric acid, although the end product both in the former and in the latter case is boric oxide. The slags which are produced on the surface of the liquid solder in brazing with BM-1 flux, in the form of a thin protective film, are an obstruction to the evaporation of zinc. At the same time, at optimum consumption of flux, which is 20-35 grams per kg. of solder (the third division in the FGF-1-56 flux feeder) the slag covering does not retain gases arising from the solder at the moment when it hardens. But in brazing with boric acid, as a consequence of difficulty in administering the proper amount manually, the slag covering may become an obstacle to the elimination of gases, and the seam may have high porosity.

Thus in brazing with copper-zinc solders and BM-1 flux the evaporation of zinc from the solder is eliminated, which increases the tightness of the seam, and also improves the sanitary-hygienic conditions under which the brazer does his work. With automatic feed of flux the productivity of labor increases and the qualitative properties of the process become stable. The slags forming in this instance upon the surface of the brazed article are easily removed by merely washing with cold water.

The most effective use of this flux is in the braze-welding process with copper-zinc solders. In capillary brazing, since the gas does not enter the gap, double fluxing is required (see page 85).

All of the fluxes listed above are insufficiently active to be used in brazing rust-resistant steels and alloys. In order to remove the high-melting-point oxides of chromium it is indispensable to introduce fluorides (of potassium, sodium, etc.) into them. The addition of fluorides to boric fluxes, moreover, increases their fluidity and improves their flow into capillaries.

In domestic industry, in the brazing of rust-resistant steel there are used fluxes 200 and 201, and flux 200 is put out on a centralized basis by the Novosibirsk plant for rare metals. It is recommended for brazing structural and stainless steels, for example, with copper-zinc solders at a temperature of 850-1100° C.

Flux 201 is more active than flux 200, but its preparation is more complicated, since it contains an aluminum-copper-magnesium bonder. It is used for brazing heat-resistant alloys, structural and stainless steels, by means of brass, heat-resistant, and other solders. The flux is active at temperatures of 850-1100° C.

Table 27
Compositions of fluxes for brazing with high-melting-point solders

Brand of flux	Chemical composition	Quantity %	Field of use	Brazing temperature °C
209	Boric oxide (B_2O_3) Anhydrous potassium fluoride Potassium fluoroborate (KBF_4)	35±2 42±2 23±2	Brazing of stainless steels, heat-resistant alloys, construction steels, and copper alloys	620—850
284	Boric oxide (B_2O_3) Anhydrous potassium fluoride (KF) Potassium fluoroborate (KBF_4)	24±1 35±2 42±2		650—850
18B	Boric acid (H_3BO_4) Potassium fluoride(KF)	60 40		650—850

The second group of fluxes (table 27) is used for brazing with the lower melting point solders among the category of the high-melting-point ones. For example, with these fluxes brazing is done with solders PSr45, PSr40, etc.

Since fluorine compounds form part of these fluxes they are suitable for brazing stainless and heat-resistant steels. The least active of all the fluxes referred to is 18B. It commences to flux relatively actively in the temperature range 650-850°, and for this reason it should not be used for brazing with solders PSr50 and PSr40 which have a melting temperature of 650° and 605° C respectively. All the fluxes of this

group lose activity at a temperature higher than 850° C. One must give heed to the fact that at a temperature higher than 750° C the potassium tetrafluoroborate which forms part of the composition of fluxes 209 and 284, disintegrates with formation of boron fluoride, which is harmful for the health of workers; for this reason brazing must be done under an exhaust draft.

After brazing with these fluxes articles must be thoroughly washed, as remnants of them give rise to corrosion. Articles of stainless steels and copper alloys must be wasted successively in hot water at 70-90° C and in cold water. Construction steels are cleaned by washing in a 2-3% solution of sodium or potassium bichromate at 70-90° C for 20-30 minutes, then in a 1% solution of the same composition at room temperature, with subsequent thorough rinsing and drying.

Fluxes for brazing aluminum and its alloys

Even without heating, there forms on the surface of aluminum and its alloys a tight oxide film, difficult to melt, of Al_2O_3, which obstructs the brazing process. Ordinary fluxes cannot disintegrate or reduce it. The method of brazing with mechanical breaking-up of the film (with a steel brush, abrasives, etc.) is familiar, but it does not ensure good wetting with solder over the whole surface, and the process becomes very labor-consuming. A more efficient method is the chemical dissolution of the film through the use of special fluxes (table 28).

The most widespread flux in brazing aluminum is flux 34A (developed by S. N. Lotsmanov). The mechanism of its functioning is based upon a complex of thermic, chemical, and electrolytic effects.

During the first moments of heating, as a result of the difference between the coefficient of heat expansion of the basic metal, aluminum, and the film of Al_2O_3, small cracks are formed in the latter. The sodium fluoride which forms part of the flux opens up these cracks through partial disintegration of the aluminum oxide. Zinc chloride, interacting with aluminum according to the reaction

$$3ZnCl_2 + 2Al = 2AlCl_3 + 3Zn.$$

penetrates into the islets of pure aluminum which form between the cracks. The zinc which is freed plates the surface and thus ensures wetting with solder. The aluminum chloride in gaseous form separates into the atmosphere, on the way contributing to the break-down of the oxide films and to their dissolving into the flux. A defect of this flux is its relatively high melting point and its high corrosional activity; for this reason it can be used only for articles which can be washed after brazing.

Table 28

Components and properties of fluxes for brazing aluminum and its alloys

Brand of flux	Chemical composition in %								Melting temperature in °C
	KCl	LiCl	NaF	$ZnCl_3$	$CdCl_2$	NH_4Cl	Eutectic* $KFAlF_2$	Mixture of fluorides **	
34A	50	32	10	8	--	--	--	--	420
F380A	47	38	5	10	--	--	--	--	380
17	51	41	--	--	--	--	8	--	380
F370A	47	38	5	--	10	--	--	--	370
F220A	--	--	--	90	--	8	--	2	220

* The eutectic consists of 46% KF and 54% AlF_3

**29% LiF, 59% KF, and 12% NaF

Thus for radiotechnical apparatus where washing in water is out of the question, this flux is unsuitable. Its high melting point (420° C) makes necessary the use of relatively high-melting-point solders, such as brands 34A, 35B. At the same time the use of such solders makes the brazing process difficult, especially on articles having delicate sections, since this may cause them to melt.

The subsequently developed fluxes F380A, 17, and others have a lower melting point, which has made it possible to expand the assortment range of solders for brazing aluminum. The fluxes referred to above, as well as flux 34A, are active in producing corrosion.

Fluxes for brazing magnesium alloys. In brazing magnesium and its alloys high-melting-point magnesium oxide and magnesium hydroxide ($Mg(OH)_2$), which forms upon the heating of magnesium to 300° C, must be removed. None of the fluxes examined above will ensure the removal of magnesium hydroxide.

A satisfactory quality of joints is ensured in brazing with fluxes the contents of which are given in table 29. The fluxes described are hygroscopic, and they must be kept in hermetically sealed vessels. A defect of the majority of these fluxes is the relatively high specific gravity, which makes it difficult for them to evacuate from the seam; but the remnants of the fluxes contribute to the development of corrosion in brazed joints, for which reason they must be painstakingly removed.

Table 29

Compositions of fluxes for brazing magnesium alloys

Brand or Number	Melting point °C	Chemical composition in %						
		KCl	NaCl	LiCl	SrCl	Na_3AlF_6	KF	NaF
8	435	35	35	20	5	—	5	—
12	380	31,5	9	49,5	—	2	—	8
F380Mg	380	42,5	10	37	—	0,5	—	10

V. The Construction Of A Brazed Joint

In brazing the selection of the structure of the joint is of exceedingly great importance. Solders have lower mechanical properties than the basic metals to be brazed. But through proper selection of structure it is possible to produce joints of equally great strength.

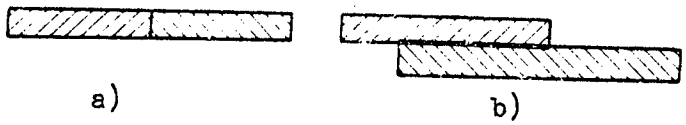


Figure 23. The main types of joints in brazing.
a) Butt joint; b) Lap joint

In brazing there are two main types of joints: butt and lap (figure 23). In practice these two types of constructions are varied in brazing practice.

On account of the small brazed area, a butt joint has relatively low mechanical properties; for this reason it is very rarely used, only in cases which do not admit of increasing the thickness of the article at the place of brazing. Variants of the butt joint are the inclined butt and the toothed joint (figure 24, b, v, g) in which, by increasing the surface area of the seam, it is possible to increase its strength. Such types of joints are used for brazing band saws, manufacturing containers, etc. A deficiency is the increased amount of mechanical processing of parts before brazing and the complicated process of setting them up during the brazing process.

Butt joints are used for articles working under insignificant loads and not requiring hermetic tightness.

The most widespread joint is the lap joint, in which (figure 23) the surfaces of the parts to be brazed partially cover each other, which ensures increase of the strength of the seam.

By modifying the area of overlap it is possible to ensure conditions under which the strength of the brazed joint will be equal to the strength of the most delicate or of the least substantial of the parts to be welded. Maximum strength of the brazed joint will be secured in this case when the size of the overlap is equal to approximately two to three thicknesses of the more delicate component of the brazed joint.

The length of overlap which ensures strength of joint equal to the material may be determined according to the formula

$$L = \frac{\sigma_n \delta}{\sigma_{cp}},$$

where L is the length of overlap in millimeters;

σ_s—is the tensile strength of the more delicate part of the brazed joint under fracture in kg per square centimeter;

σ_{cp}—is the shearing tensile strength of the brazed joint in kilograms per square centimeter;

δ—is the minimum thickness of the brazed part in millimeters.

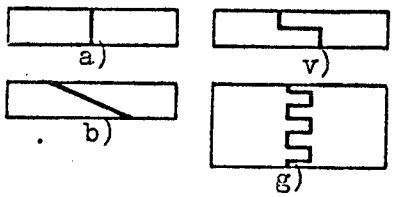


Figure 24. Variants on butt joints:
a) Straight butt; b) Oblique butt;
v) Stepped butt; g) toothed butt

Brazing is widely used in making pipe joints. In these cases the preference is again given to overlap ones. The most widespread types of pipe joints are shown in figure 25. In the cases where increase of the outside diameter of the pipe at the place of brazing, with retention of the inside diameter, is permitted use is made of types a and v. If it is indidpensable to preserve unchanged the outside diameter of the pipe, but it is possible to reduce its inside diameter, the constructions b or g are used. The length of the expanded part of the pipe (the size of the lap) or the length of the sleeve are determined, with an eye to equality of strength, just as for flat joints.

T-joints are used very rarely in brazing. But in this case the best results are secured by flanging the edge of one of the parts, i.e. by bringing about a lap joint (figure 26). In order to get sealed vessels lock joints are sometimes used.

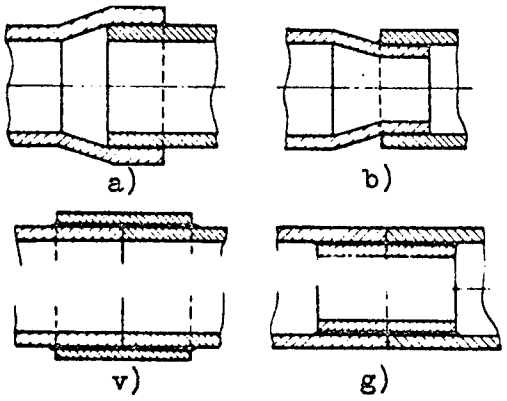


Figure 25. Tubular joints

The likelihood of warping and distortion is much less in brazing than it is in welding, but in brazing too, in setting up joints, it is indispensable to take into account that these phenomena may set in.

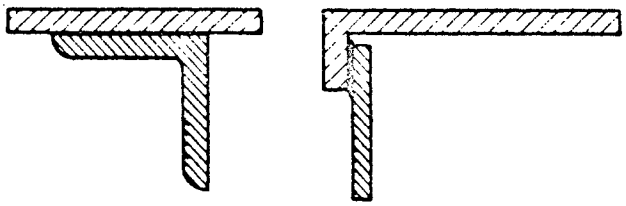


Figure 26. T-joints.

In particular in brazing pipes with flanges, in order to reduce warping in the collar the thickness of the latter should be greater than the thickness of the pipe.

Pipes with inset bushings can be brazed only in cases when a low degree of accuracy in the coincidence of the axial lines is permissible. If there are imposed upon the part requirements of the fourth and fifth classes of precision, it is recommended that the thread be cut after brazing.

The size of the gap between the parts to be brazed has a considerable influence upon the properties of the brazed joint. The optimum size of gap depends on the properties of the metal brazed and of the solder. As we are aware, the formation of a brazed seam takes place through the filling of the gap between the surfaces to be brazed with fluid solder, under the influence of capillary forces and sometimes the force of gravity.

Consequently the size of the gap should meet the requirements which ensure the formation of capillarity.

In the majority of cases improvement of the properties of a brazed seam as compared with the solder is explained by the dissolving in the latter of the basic metal which is being brazed. If the basic metal and the solder interact energetically one with the other, the gap may be made larger, or vice versa.

Thus, for instance, aluminum solders have a great capacity for reacting, for which reason in the brazing of aluminum relatively large gaps are recommended.

Steels dissolve little in solders, for which reason brazed joints in steel should have the smallest gaps possible (table 30).

The gaps indicated in table 30 are optimum ones. With smaller gaps the solder will not flow in them, which will lead to the appearance

Table 30
Recommended gaps in brazing various metals

Solders	Gaps in mm for the metal brazed		
	Copper & its alloys	Steels	Aluminum and its alloys
High-melting-point:			
Silver.....	0.05-0.25	0.03-0.12	--
Brass.....	0.075-0.3	0.12	--
Aluminum.....	--	--	0.1-0.3
Low-melting-point.....	0.05-0.15	0.05-0.15	--

in the seams of flaws and loosenesses. Gaps within the limits indicated in the table can be ensured only in parts made by machining or by stamping.

For parts made by boiler-shop or coppersmith methods, it is technically impossible to keep the gaps within these limits. In such cases the parts must be fitted with such precision that the average size of the gap, for example in brazing with low-melting-point solders, does not exceed 1 mm. with admissibility of local increases of gap to 2 mm over a length not exceeding more than 10% of the overall length of the seam.

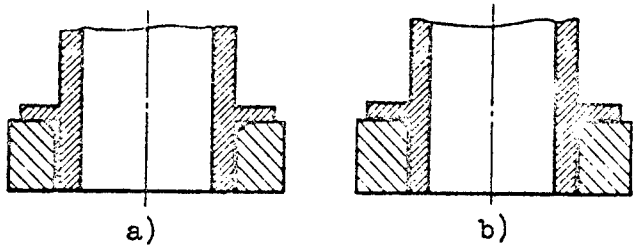


Figure 27. Influence of consistency of gap size upon formation of brazed joint. a - Incorrect construction; b - Correct construction.

With such large gaps as this capillary forces may be dissipated, for which reason such joints must be designed in such fashion that in brazing their being filled with solder takes place under the influence of gravity, to which end the solder is to be fed in from above. In these cases there must be provided, in the lower part of the joint, a backing which will keep the solder from running out.

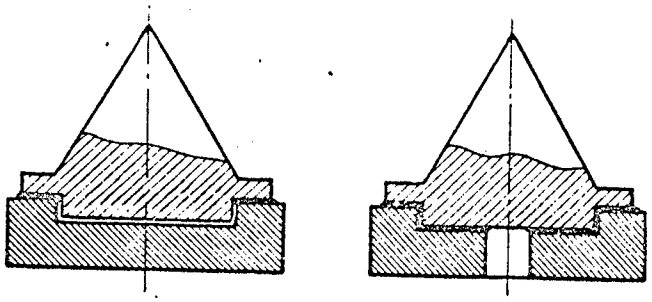


Figure 28. Conditions indispensable for exiting of gases. a - Incorrect construction; b - Correct construction.

It is very important in brazed joints, no matter what the size of gap, to preserve the evenness of its dimensions. Broadenings, chamferings, etc. which spoil capillarity, are inadmissible (Figure 27).

In designing a brazed joint it is also indispensable to take into account the fact that for the flowing of the solder into the gap it is necessary to create conditions in the brazing process which will permit exiting of air or gases which are within the nucleus; for this reason, in brazing dead-end joints, it is necessary to make technological openings (Figure 28).

VI. The Technology Of Brazing

The technological process of brazing consists of several consecutive operations, upon the quality of the execution of which the properties of the brazed joint depend.

1. Preparation of Articles for Brazing

The wetting of the surface to be brazed by the solder and the flowing of the latter over this surface, without which a strong engagement between them cannot be secured, are possibly only when there is careful cleaning of the site of the braze from dirt, greases, oxide films, etc. The fluxes used for welding to a certain degree cleanse the parts of dirt. But it is not sensible to make use of the flux for this purpose, because this prolongs the process of brazing and calls for longer and stronger heating.

Systems for preparing parts for brazing depend on the character and degree of the soiling of the surfaces to be brazed.

Greases and dirt are eliminated in organic solvents (gasoline, trichlorethylene, etc.) and in alkaline solvents; in the latter both chemical and electrochemical methods may be used. The de-greasing of small parts of complicated shape is possible with the aid of ultrasonics in special baths containing benzine, or benzine with acetone.

After de-greasing, the articles are washed in hot water, and then in cold water, after which, if necessary, they are pickled. Scale and oxide films are ordinarily removed mechanically.

A thick layer of scale, rust, or paint can be removed with a pneumatic hammer, fire cleaning, etc. Cleaning with a file, a grinding wheel, or a sand blower is possible. In the last case one must bear in mind that the grains of sand may be an obstacle to wetting of the surface of the part with solder, and for this reason they must also be removed. Small parts may be cleaned in special rotating drums with sand or steel shot. One should bear in mind that solder spreads better and fills capillaries better if the surface is rough. The small unevennesses and channels which are formed in this process play the part of small capillaries, contributing to better spreading of the solder. Solder spreads badly on polished surfaces.

Mechanical cleaning of surfaces is used for the majority of metals, excepting aluminum, magnesium, and their alloys, for which better results are secured by chemical pickling.

The systems of de-greasing and pickling applicable to various metals and alloys are presented in corresponding sections devoted to the technology of brazing the specific metals.

2. Fitting together and fluxing articles to be brazed

Gas-flame brazing is to date predominantly a manual process, and for this reason the question of fitting together parts for brazing, which determines the convenience of the brazer's work, takes on great significance. In the brazing process the hands of the brazer are engaged with the burner and the solder, and therefore the parts must be well set up and fastened.

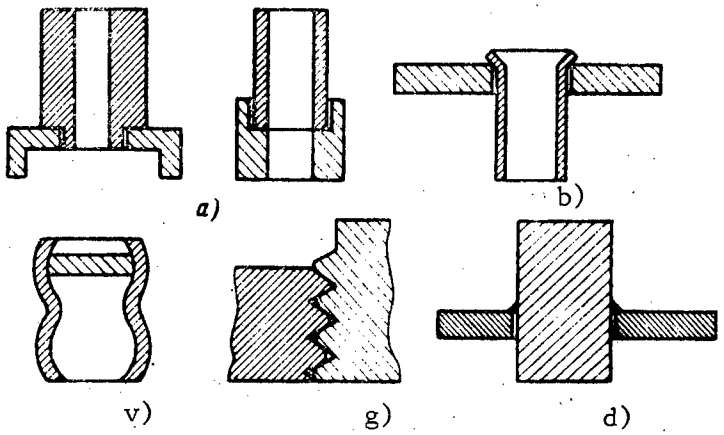


Figure 29. Setting up of parts for brazing.
a) Presence of a shoulder; b) an expansion;
v) crimping; g) threading; d) spur clamping.

It should be easy to turn them for heating, for putting on solder and flux, from all sides with the aid of the simplest instruments.

In cases where this is possible, the setting up and fastening of parts should be carried out by virtue of appropriate design of the parts, i.e. the joining should be of a character which fastens itself (figure 29, a - g).

It is possible to join elements with clamps which will be filled out by the braze, or with mechanical jams (figure 29). Parts may also be fastened by setting up indexers (figure 30).

When the parts are fastened in a holder the latter should ensure the following:

1) free access of the flame of the burner to the article to be brazed, convenience in bringing up solder and flux; it is necessary to create conditions permitting observation of the degree of heating and of the filling of the gap with solder;

2) possibility of turning the article (particularly in brazing annular seams);

3) minimum absorption of heat;

4) in series brazing of parts of a single type, possibility of setting up several parts at one time, which increases productivity of the auxiliary operations and ensures simultaneous heating thereof.

In order to secure the least possible heat absorption the parts are set on refractory brick. Metal structures are heat-insulated with asbestos. In figure 31 there is shown a very simple arrangement for brazing heads to the tubest of oxy-acetylene cutters. Six units are set up simultaneously in the holder. When the first part is being heated, the second is getting a pre-heating from the flare of the flame, etc. The holder is made of steel, but at the places where it touches the parts to be welded it is covered with asbestos.

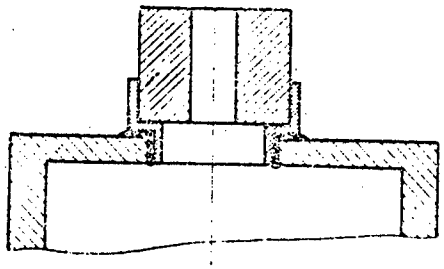


Figure 30.

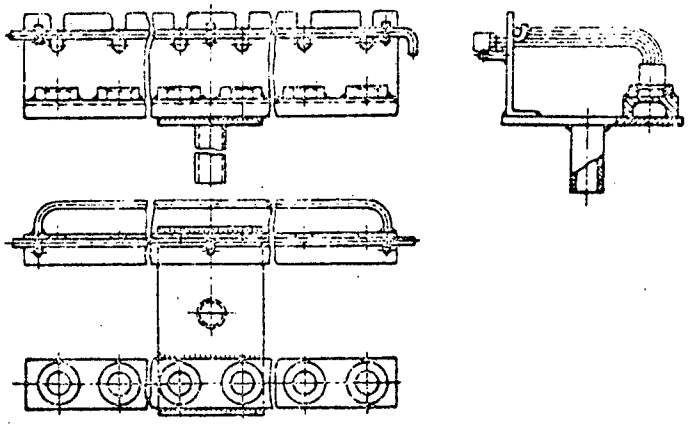


Figure 31. Holder for brazing heads of cutters to tubes.

To save combustible gases and to speed the process of heating the units to be brazed should be sheltered from the effects of cold air by brick, asbestos, etc. Moreover, when screening brick is used the speed of heating is increased through heat radiation from the brick. Experiments have shown that in the heating of small brass tubular articles with a brick screen set up back of the part and perpendicular to the flame, the speed of heating is increased on the average of 1.5 to 2 times.

Gas-flame brazing is carried out with the use of flux. An exception is brazing of copper with copper-phosphorus solders, which can be done without flux. Flux can be put on as powder or paste, and also it can be introduced in a vaporous condition together with the combustible gas in the flame of the burner.

In the first two cases it is not recommended that the flux be put on a part already heated for brazing, as by reason of the absence of the protective action of the fluxes the inner surfaces of the parts to be joined will oxidize, and the normal process of the filling up of the gap with solder will not run its course. The flux must be put on beforehand upon the cold or slightly warmed part. When in the form of powder it is applied to the article with the end of a heated rod or strip of solder, which is periodically dipped in the vessel containing the powder. This way of applying flux does not ensure a stable protection of the place of brazing from oxidation, because to apply it evenly is practically impossible, and besides part of the powder is blown away by the flame.

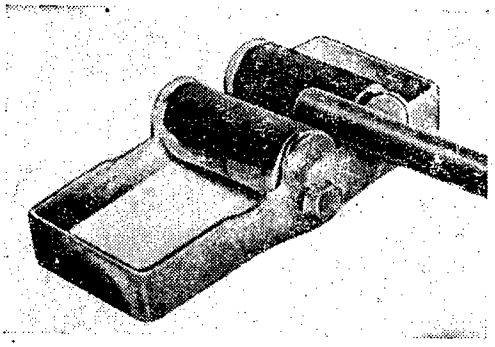


Figure 32. Apparatus for applying flux.

The best results are secured by using flux in paste form. The paste is ordinarily mixed with water or alcohol and is applied with a scrubbing brush or an artist's brush. In brazing tubular articles the flux may be applied with the aid of a very simple device shown in figure 32. Flux must also be put on the solder in order that it may not oxidize in the process of heating.

In brazing lap joints (if the size of the lap is more than 5 mm) it is recommended that the flux be applied to one of the parts to be welded before assembly. Flux must be applied more abundantly to the edge of the joint, and considerably less should be introduced into the gap, so that there may be no remains of slag in the seam. An excess of flux on the edges of the joint to a certain degree obstructs the entrance of air into the gap and consequently reduces the oxidation of the surfaces to be brazed.

In brazing with BM-1 brand flux in gas form it is indispensable to use double fluxing, for in the contrary case the solder will not flow into the gap over the whole size of the lap, and the brazing will be carried out at the cost of the formation of hollow places. For this reason when using BM-1 flux it is necessary to introduce into the gap a small quantity of the flux ordinarily used. This is necessary because the flame penetrates badly into the gap and fluxes the inside edges poorly. Oxidation of the inside edges is very slow, since practically it all takes place on the basis of the content of oxygen in the air which is within the gap; a new influx of air is made difficult by the protective action of the flame, which contains flux.

In order to ensure the fluxing of inside edges it is sufficient to wet one of the parts to be brazed (preferably the one set inside) to the extent of the lap, by dipping it into a water solution of borax, and in brazing parts of copper and steel with L 62 solder it is sufficient to use a 10% water suspension of borax for this purpose.

In brazing copper parts it is possible not to apply flux in paste form - it is enough heat up a little with the flame containing flux the end of one of the parts to be welded, before assembly.

This kind of double fluxing, although it somewhat prolongs the preparatory cycle of the brazing, nevertheless appears logical, because in this case there are on the surface of the articles no slags which are difficult to remove, and, the main thing, the qualitative indices of the process are sharply improved, i.e. the brazed joint becomes much stronger. The last occurs because there is no inclusion of flux in the metal of the seam, and in brazing with copper-zinc solders there is no evaporation of zinc.

A test braze was carried out on a large batch of steel parts with L62 solder. The brazing of one portion of the parts was done with borax, that of the other with BM-1 flux.

In testing the strength of the brazed seam with a haloid leak detector, the samples being filled with Freon, in the first batch there were found loose spots in 10% of the parts, and in the second batch a whole 100% of the parts proved to be gas-tight.

Sometimes before brazing the spot of the braze is covered with some sort of metal or alloy. Thus, for example, in brazing with low-melting-point solders it is recommended, in order to improve the quality of the process, that the spot of the braze be tinned in advance. Tinning the spot of the braze with solder is ordinarily done by the hot method. It is recommended that this be carried out not more than 48 hours before the brazing. If there are longer intervals the tinning oxidizes and the effectiveness of its functioning during brazing falls off sharply.

It is possible to tin manually through the use of heating via the flame of a burner, a blowtorch, or other sources of heat, or through immersing the part in melted solder. Moreover, the layer of tinning may be applied by the galvanic method. But the layer secured in the last case, in order to improve bonding, should be converted into a layer of hot tinning by melting it. The flux for the tinning is selected on the basis of general recommendations. If, however, there is a possibility of carefully washing the parts after tinning, then preference should be given to the active fluxes. The use of the latter speeds the process of tinning and ensures a high-quality tinning. A tinning layer 0.02 - 0.05 mm. thick is recommended.

3. Technique of Brazing

After the part has been fixed in the holder and covered with flux, heating it for brazing is started. An important factor affecting the quality of the braze and the productivity of the process is the composition of the combustible mixture fed into the burner.

An oxy-acetylene flame has its highest temperature when the proportion of the consumption of oxygen and acetylene is $\beta = \frac{O_2}{C_2H_2} = 1.4$. With a normal flame, i.e. with $\beta = 1.1 \div 1.2$, its temperature is close to the maximum. In brazing the normal flame is used for the most part, or one with a small excess of acetylene.

Experiments have shown that in brazing with copper-zinc solders the best quality of brazed seam is secured with heating in an oxidizing flame. This may be explained by the fact that upon heating with an oxidizing flame the melted metal is covered at the first moment by a layer of oxides obstructing the further evaporation of the zinc. Upon heating with a reducing flame the protective covering does not form. Moreover, the suggestion is made that the more intensive evaporation of zinc in this case occurs on the basis that the hydrogen absorbed by the melted bath from the flame creates an additional surface for the evaporation of zinc, thereby increasing the loss thereof.

But one must bear in mind the fact that in brazing steel with copper-zinc solders an oxidizing flame increases the likelihood of the formation of cracks in the basic metal.

The power of the flame or the power of the burner is determined by the quantity of the acetylene or other combustible which passes through the burner in liters per hour.

The power of the flame is selected depending upon the thickness and heat conductivity of the metal to be brazed, and - which is the main thing - upon the melting point of the solder selected.

In brazing with high-melting-point solders the power of the flame can be determined tentatively just as in gas welding, i.e., in the latter case the power of the flame is determined by the following formula:

$$Q = k\delta$$

where Q - the consumption of gas in liters per hour;
δ - the thickness of the more massive part, or of the one having the greater heat conductivity, in millimeters;
k - a coefficient depending upon the nature of the metal.

The value of k for various metals is as follows:

Carbon steel	100-120
Stainless steel	not more than 70
Copper	150-200
Brass	100-120

In brazing the parts are ordinarily heated up in the broad part of the flame (the outer flare), which is approximately at a distance of 10 millimeters from the core. In brazing heavy elements it is recommended that a burner with a multijet or sieve mouthpiece be used, as it gives a softer flame and ensures an even heating of the important surface. In this case, without fear of over-heating, it is possible to set the mouthpiece closer to the surface to be brazed, i.e. to heat with a higher-temperature part of the flame.

In contradistinction to the case with welding, one should strive to heat a considerable part of the joint evenly and at one time to the working temperature of the solder. In order to ensure even heating the burner is given a to-and-from motion.

When parts in differing metals or of differing thicknesses are being heated the flame should preferentially be directed at the one of them which has the higher heat conductivity or the greater thickness. Sometimes, if the difference in thickness of parts is very great, a delicate part is heated up through the heat of a thicker one.

Solder is brought to the spot of brazing when the parts are heated up to the temperature of the melting of the solder. It is flowed on by virtue of the heat of the parts and partially the heat of the flame. It

must not be spread wholly by means of the flame and applied to a badly heated part. At the moment the alloy is but at the spot of the braze the burner is moved a little away from the article, and then it is shifted to the next sector of the joint which is to be brazed. The alloy fills the capillary and its shifted ahead to where the flame is.

It is essential to bear in mind the fact that the solder must be brought to the spot of brazing after the melting of the flux and its filling of the gap. An experienced brazer determines the temperature of the heating by the tempering colors (with low-melting-point solder) or by luminosity. Moreover, heat pencils can be used to check temperatures up to 600° C. In this case the temperature of the heat is determined by the change in the color of the indicator of the appropriate heat pencil, which has first been applied to the surface of the part at a point about 20-40 millimeters distant from the point of brazing.

Solder is applied most frequently in the form of a rod, a wire, or a ribbon. The section of the rod or ribbon is taken as being equal to 1 to 3 thicknesses of the more delicate element of the article to be brazed.

Too delicate a section of solder prolongs the process of brazing, while with too great a section there arises the need for overheating the article, since the solder melts by virtue of its heat.

In manual brazing the solder, as a rule, is not put into the joint to be brazed in advance, but is applied from outside. An exception is brazing with PMTs solders, which are used in the form of powder in mixture with borax. The mixture thus made is dissolved to the consistency of porridge with water and is applied to the point of brazing with an artist's brush.

Upon the conclusion of the braze the article must not be moved until the solder has completely hardened, in order that cracks in the brazed seam may be avoided.

4. Processing of Components Subsequent to Brazing

After the process of brazing has been carried out the brazed seams are cleaned of remnants of fluxes and of slags that have formed, and the article is straightened, or heat-treated if that is required.

Removal of remnants of fluxes is necessary because in some cases they provoke corrosion. Cleaning systems are determined by the compositions of the fluxes. Borax is removed mechanically or by prolonged boiling in water. For this purpose sand-blast cleaning is also used. Remnants of slags from brazing with BM-1 flux are easily washed away with water. Remnants of hygroscopic fluxes are removed by washing in hot and then in cold water.

Fluxes containing haloid salts are easily removed by washing with water. These salts, in consequence of their hygroscopic character, constitute a great danger as regards corrosion. For this reason they must be washed away not later than one hour after brazing. Fluxes on a zinc chloride base are easily removed by washing.

After brazing copper and brass components with the use of fluxes on a zinc chloride base the point of brazing and the surfaces in its near vicinity may be covered with copper oxides. In order to remove the oxides the article should be treated for 10-15 minutes in a special passivizing solution of the following composition:

Potassium bichromate ($K_2Cr_2O_7$)	130 grams
Sulphuric acid (H_2SO_4)	80
Sodium chloride (NaCl)	1.0
Acetic acid (CH_3COOH)	50
Water (H_2O)	1 liter

The temperature of the solution is 40-50° C. Next there follows washing in cold and then hot water and drying. For articles of large dimensions and complicated shapes brazed with tin-lead solders and the use of corrosion-active fluxes, one may make use of treatment with a 10% solution of potassium bichromate heated to a temperature of 60-70° C. The article is either immersed into a bath of the solution indicated entire, or the solution is poured into the interior cavities of the article for 2 - 8 hours. After removal of the solution the articles are washed in hot water and dried with warm air.

VII. PECULIARITIES OF BRAZING CERTAIN METALS AND ALLOYS

1. Brazing Carbon and Alloy Steels

Low-carbon and low-alloy steels are among the category of metals that braze well. The process of brazing does not give rise to any difficulties, but with increase of the carbon content of the steel the process becomes somewhat more complicated, since there arises the possibility of hardening of the steel in the region of the braze, and consequently there also increases the likelihood of cracks appearing. In order to avoid the latter, it is indispensable to select solders having a working temperature of brazing which is below the hardening temperature of the steel. Moreover, in these cases slow cooling of elements after brazing plays a favorable role. The preparation of carbon and low-alloy steels for brazing can be done by any of the methods recommended above.

In order to remove oxides from the surface pickling in sulphuric and hydrochloric acids is used. The best results are ensured by a mixture of these acids. The content of sulphuric acid may range from 5-10% and that of hydrochloric acid from 2-10%. In addition, there is added to the bath a KS or ChM additive to the amount of 0.2% of the weight of the liquid, which prevents overpickling and hydrogenation of the surface of iron and steel.

For brazing these steels there are used, among the low-melting-point solders, primarily the tin-lead ones, and among the high-melting-point solders, primarily the copper-zinc and silver ones. Copper-phosphorus solders are not used.

In order to remove oxides and protect against oxidation, active fluxes are used in brazing with low-melting-point solders; in brazing with high-melting-point solders, depending on their melting temperature, borax, BM-1, 209, V18, etc., are used. Powder fluxes are applied in the form of a water paste, or better still an alcohol paste, and are put on before the elements are heated up.

Brazing with low-melingt-point solders is used preferentially for joining thin-wall articles. One must bear in mind the fact that in brazing zinc-plated iron it is necessary to avoid tin-lead solders containing antimony, since at the border of melting there takes shape a brittle streak conjunction of zinc with antimony, as a result of which the strength and the plasticity of the joint falls off.

The properties of brazed joints in steel carried out with various low-melting-point solders are given in table 31.

Table 31

Brand of solder	Tensile strength on shearing, in kg per square millimeter			Tensile strength on breaking, kg per sq. mm., steel, iron
	steel, iron	zinc-plated iron	tinned sheet iron;	
POS; 40	6.1	4.7	4.9	10.1
POS; 30	5.0	4.2	3.6	11.5
POSS; 4-6	4.9	2.6	4.5	10.3

In brazing steel better results are ensured by copper-zinc solders, alloyed (table 32) with silicon and tin (LOK-59-1-03 and others).

In brazing with simple brass, for example brand L62, more solid seams with a high strength index are produced with flux EM-1. In the latter case the shearing strength comes on an average to 32.3 kg per square mm as compared with 27 kg per square mm.

In brazing with brasses there is less fuming of zinc and there are stronger seams if heating is done with an oxidizing flame.

Experiments which have been carried out show that brazing with an oxidizing flame ($\beta = \frac{O_2}{C_2H_2} = 1{,}3 \div 1{,}4$) leads to increase of tensile strength upon shearing by an average of 11%, and of plasticity (angle of bend) by 16% in comparison with those secured in heating with a normal flame.

Table 12

Properties of brazed joints in Standard No. 3 steel

Brand of solder	Tensile strength on stretching, in kg/cm^2;	Resistance to shear in kg/cm^2	Bending angle in degrees
PMTs; 48	$\frac{27{,}8—34{,}0}{31{,}3}$	$\frac{18{,}0—25{,}0}{20{,}9}$	$\frac{5—25}{12}$
L62	$\frac{40{,}6—44{,}8}{43{,}0}$	$\frac{25{,}0—33{,}3}{27{,}3}$	$\frac{30—102}{63}$
LOK 62-06-04	$\frac{41{,}0—45{,}6}{43{,}8}$	$\frac{30{,}2—33{,}4}{31{,}6}$	$\frac{62—86}{72{,}5}$

Note: In the numerator there are given minimal and maximal values, in the denominator mean arithmetical values secured from no less than 7 tests.

At the same time one must bear in mind that an oxidizing flame, being one of higher temperature, may lead to overheating and, in addition, to decarburizing of the parts being brazed. In the aggregate these two phenomena increase the tendency of the steel to crack under the effect of brass penetrating along the edges of the grains of steel.

In figure 33 there is presented a tubular electrical heater which consists of a steel tube brazed with L 62 brass to a steel bushing.

At the place where the seam has formed there are clearly distinguishable cracks in the steel tube. Investigation of the structure of the brazed joint showed that the surface of the tube at the point of heating preparatory to brazing was overheated and decarburized, evidence of which is the coarse-grained structure of the steel and the complete disappearance in it of the pearlite component (figure 34.) The brass has penetrated along the edges of the ferrite grains (figure 35) and has occasioned the formation of cracks. The character of the structure of the steel bears clear witness to the fact that it was overheated with an oxidizing flame.

In brazing with silver solders no particular difficulties arise.

The brazing of high-alloy steels, and above all that of stainless steels, is made complicated by the high durability of the oxides which form on their surfaces upon heating. It is difficult to remove the oxide film primarily in brazing steels alloyed with chromium, aluminum, titanium, and silicon. But at present there have been worked out special fluxes - for example, 200,201,209, etc. - which remove films of such oxides, and in this case the process is little distinguished from that of brazing ordinary steels.

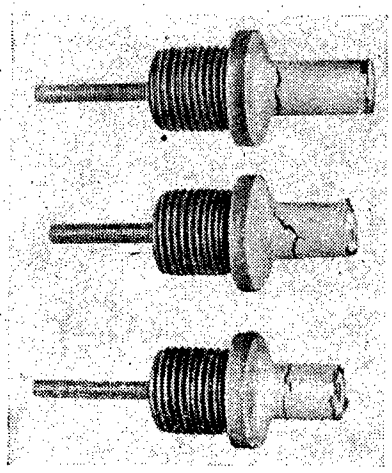


Fig. 33. Tubular electrical heating element.

The preparation of parts in stainless steel for brazing is also made difficult by the presence of oxides which dissolve badly. Ordinarily these are pickled in water mixtures of sulphuric, nitric, hydrochloric, and other acids. It is possible to pickle in 20-30% hydrochloric acid at a temperature of 60-80°C for several minutes until the appearance of an even black coating, which is removed by washing in water with the use of scrubbing brushes.

In brazing with low-melting-point solders fluxes 200 and 201 are used; with silver solders, fluxes 209 and 18 B. One must take into account the fact that chrome-nickel stainless steels, for example brand 2Kh18N9, containing no titanium or niobium (unstabilized) lose their corrosion resistance upon being heated to a temperature range of 500-800°C approximately. For this reason the use of solders having a working temperature within the critical range indicated during the brazing process is not recommended for them.

Fig. 34. Structure of brazed seam at the point of overheating (X200).

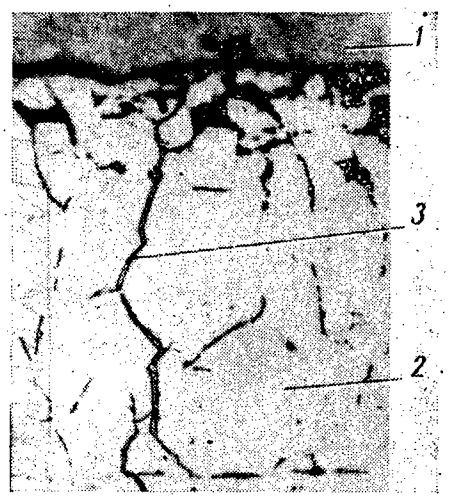


Fig. 35. Brazed joint at the point of penetration of brass into the steel (X200): 1. - Seam; 2. - Basic metal (steel); 3. - brass.

Better results are ensured upon brazing these steels with solders which have a melting temperature above 800°C, or with the lowest melting-point one among the standard silver solders, brand PSr40, the working temperature of which in brazing comes to approximately 620°C. This solder is also recommended for brazing hardened steels.

High-chromium steels, for example brand 1Kh13, do not lose their corrosional properties upon heating to 900° C; for this reason it is possible to braze them with any silver or copper-zinc solder. One must bear in mind the fact that some steels of this group in their cold-worked state are inclined to brittle fracture upon contact with liquid solder. For example, the most widespread stainless steel, brand 1Khk8H9T, may crack in contact with liquid brass or silver solders.

Steels inclined to brittle fracture which are intended for brazed constructions must be used in annealed or normalized state.

Since all fluxes for brazing high-alloy steels are as a rule hygroscopic, remnants there of after conclusion of the process must be painstakingly removed.

In using fluxes 200 and 201 the remnants thereof and the slags must be removed by prolonged boiling in hot water or blowing in a sand-blast apparatus.

The remains of fluxes 209 and 18B must be removed not longer than one hour after conclusion of the process. They are removed by thorough washing of the parts, first in a 2-3 percent solution of sodium (or potassium) bichromate for 20-30 minutes at 70-90°C, and then in a 1% solution of sodium (or potassium) bichromate for 10-15 minutes at room temperature.

After washing, small elements must be dried at 150-180°C. The time the elements are kept under drying is determined by when the entire element reaches 100-120°C. Delicate elements of complicated shape are more prudently dried with dry air instead of in a drying cabinet.

2. Brazing cast iron

Articles of cast iron are of widespread application in machine building, despite their brittleness, their relatively great weight, and the presence of stresses remaining as a result of the casting processes. The universality of cast iron in industry is explained by the fact that it has good casting properties, high resistance to compression and stretching, and chemical stability toward the corrosive action of some acids and alkalies.

In the manufacture of cast iron articles in domestic practice brazing is very rarely used as a method of making permanent joints. Most frequently brazing is used for repair purposes, in correcting casting defects or eliminating damage in already manufactured articles. At the same time the inculcation of the process of brazing into the practice of the production of articles in cast iron would simplify casting work, would make it possible to join cast iron with other metals, etc.

Besides, one should take into account the fact that in a whole list of cases brazing can successfully take the place of welding. In brazing,

as distinguished from welding, there is eliminated the need for the laborious operation of general, or even only the local, heating-up, and the extremely prolonged subsequent cooling. In welding cast iron without these operations (heating-up, slow cooling) particles of white cast iron, that cannot be machined, form in the seam or in the region around the seam. Inasmuch as the brazing process is carried out at lower temperatures, formation of white cast iron practically does not occur. For the same reasons, in brazing the likelihood of cracks forming in the cast iron falls off sharply.

It is primarily articles of gray and malleable cast iron that are subjected to brazing. In these cases ordinary capillary brazing, and more frequently the so-called braze-welding, are used. The brazing may be done with low-melting-point tin-lead solders, high-melting-point silver ones, but most frequently and preferentially in braze-welding, with copper-zinc ones.

In braze-welding the formation of metallic bonds between the cast iron and the solder progresses on the type of ordinary brazing, i.e., through the interaction of the liquid solder - brass - with the hard basic metal.

The technological procedures of the process (preparation of the edges, formation of the seam in separate portions, etc.) are analogous to those used in welding. The basic difficulties in brazing cast iron are associated with the presence upon its surface of structurally free graphite, which hinders wetting and the spreading of the solder over the surface. The greatest difficulty is caused by the graphite of grey cast iron, and the least by that of malleable cast iron.

In order to improve the process of wetting and flowing, steps are taken to eliminate the graphite from the surface to be brazed. The graphite is removed by compounding it with the elements entering into the flux, or by oxidation. In the latter case the surface to be brazed is heated with an oxy-acetylene flame having an excess of oxygen ($\beta = 1.3 \div 1.5$), to 700-800°C, and is then cleaned with a metal brush. The method of eliminating graphite by means of sand-blasting is not recommended, since the silicon dioxide which lodges in the pores of the cast iron in this process hinders the process of wetting and diffusion of the brass into the cast iron.

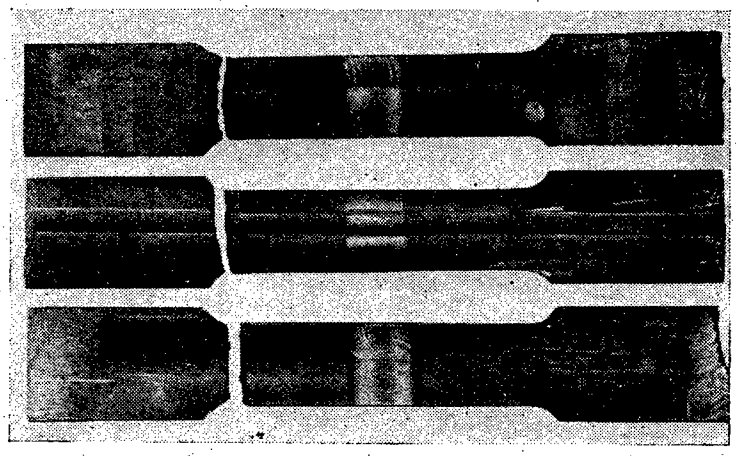
The removal of graphite by means of special fluxes is the most effective way. In particular, for this purposes a mixture of borax and boric acid in equal proportions is used. To this mixture, in order to bind the graphite, 3-5% of iron powder is added. Upon the heating of the cast iron the graphite unites with the iron in the flux, as a result of which a decarburized layer takes form upon the surface. The depth of this layer reaches half a millimeter. Such a layer takes solder readily.

By reason of the pits which are formed where the oxidized flakes of graphite have been removed the strength of the bond between the cast iron and the solder is increased. Upon heating the liquid solder runs into the capillaries formed in this way and wedges itself, as one might put it, into the cast iron.

For a long time there has been used in braze-welding in foreign practice the so-called Tobin bronze, a special brass with a composition of 57-62% Cu; 41-38% Zn; 10% Sn; 1.0% Fe, and 0.8% Mn. At present the range of solders is considerably broader.

In domestic practice for these purposes brasses of the brands L 62, LK 62-05, LOK 59-1-03, and LKN 56-03-6 may be recommended. In braze-welding with simple brass (brand L 62), in order to secure a "smokeless" process and a tight seam the use of BM-1 flux is recommended. In order to ensure wetting of the cast iron with the solder the graphite can be removed by burning or through the use of a flux containing an oxidizer. In the latter case the flux in the form of a water paste should be applied to the edges of the metal before heating up. The melting of additional metal and the formation of the seam is done with a flame containing BM-1 flux.

Figure 36. Cast iron sample pieces brazed with LKN 56-03-6 brass after fracture testing.



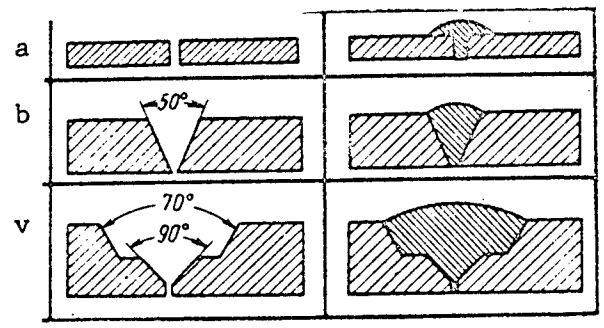
Absence of zinc fumes and a tight seam can be secured with powder fluxes by using silicon brasses. But one must bear in mind the fact that when LK 62 and LOK 59 brasses are used the first servicing layer must be filled out with simple brass L 62 (see page 57 /of original text/).

In using LKN 56-03-6 brass the need for this disappears, because by reason of the presence of nickel in the alloy its solid bonding with the cast iron is ensured.

Experiments have shown that in fracture testing a sample piece in gray cast iron (for example, SCh 15-32 brand), brazed with LKN solder, the fracture takes place in the basic metal outside the zone of the temperature influence of the braze (figure 36). LKN 56-03-6 brass gives a brazed joint in cast iron which is almost uniform with the latter in color.

As in brazing other metals, the surface of the cast iron must be cleaned of dirt, greases, oxides, etc., before the process is carried out. In capillary brazing it is important to secure an even gap within limits of 0.05 - 0.125 mm and 0.25 mm. as a maximum. In cleaning the surfaces the best results are ensured by machinging or by machine-filing.

Figure 37. Disposition of bevels in braze-welding cast iron.

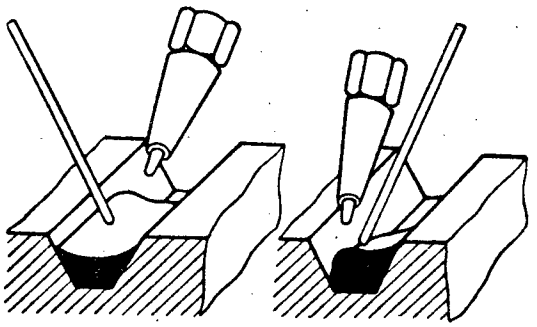


For braze-welding the edges must be backed off and carefully cleaned. The character of the backing off depends upon the thickness of the metal or the depth of penetration of a defect. For thin parts backing off of bevels is not essential. In this case the liquid melted brass, thanks to its capillarity, penetrates into the previously fluxed and heated crevice, and even strength of the seam is ensured by virtue of the formation of a reinforcement of a size equal to approximately 2/3 the thickness of the part (figure 37, a). For articles of medium and great thickness the backing-off (fig. 37, b, v) is to ensure the access of the flame of the burner to the gap.

The process of braze-welding commences with the preliminary operation of tinning the surfaces of the basic metal with brass. The temperature of heating the edges in this process must not exceed 850° C. With too low a temperature the brass will not spread and tin the surface, and with too high a temperature the metal will collect into little balls and be blown away by the flame.

Taking into account the low heat conductivity of cast iron, the power of the flame is selected at 40 to 60 liters per hour of acetylene per mm of thickness /of cast iron/. The angle of inclination of the burner to the surface of the basic metal must not exceed 40%. Heating is done by a gentle, normal flame, in which process good results are secured on condition that the hot zone of the flame is concentrated on the end of the admixture rod, and the less hot part upon the part of the basic metal which is to be tinned and which is covered with flux (figure 38, a.)

Figure 38. Disposition of flame and solder in braze-welding of cast iron



correct incorrect

With this position of the flame the wire is, as it were, a screen protecting the edge from overheating; the actual wire heats up and melts fast. This is all the more important in that the heat conductivity of the wire is greater than that of the cast iron, and its melting temperature is higher than the temperature of admissible heating of the cast iron. If these conditions are not met the basic metal is hardly wetted at all with solder (figure 38, b).

After the surface are tinned, the seam is filled with one or several passes, depending on the thickness of the part. With correct execution of the process, braze-welding of cast iron gives good wetting of the basic metal with solder and a solid bonding together of these. The tensile strength upon stretching at the border of the melt ordinarily exceeds the strength of the grey cast iron.

3. Brazing copper and its alloys

Brazing is widely used to secure permanent joints in making articles of copper and its alloys. This process is very frequently preferred to welding, particularly for articles of copper of those brands which have a high content of oxygen (M2, M3, and M4).

In welding coppers that contain oxygen it is practically impossible to secure a welded joint with sufficiently good mechanical properties.

Oxygen is contained in the copper in the form of a copper oxide, which is evenly distributed through the deformed metal, and predominantly within the grain. So disposed, copper oxide does not worsen the mechanical properties of the metal. But upon heating to relatively high temperatures on the order of 1064°C and higher the copper oxide, in the form of a brittle eutectic (copper oxide - copper), emerges to the edges of the grain and in this case the metal loses its plastic properties.

This phenomenon is observed in welding M2 and M4 brand coppers. In this case the eutectuc emerges into the transitional zone, as a result of which the welded joint takes on low plastic properties. In brazing, inasmuch as the temperature of heating, even when the highest-temperature brass solders are used, does not exceed 950° C, seams become only faintly brittle through the effect of emergence of the eutectic.

The basic difficulties in brazing copper are associated with its high heat conductivity, exceeding the heat conductivity of iron by more than 6 times. In connection with this, heating for brazing must be carried out at a high flame power; indeed, two and even more burners should be used simultaneously. As a result, along the seam a relatively broad zone is heated up, which in combination with the high coefficient of linear expansion peculiar to copper may lead to considerable deformation of constructions. In brazing copper heating must be done with a strictly normal flame. An excess of combustible gas, for example acetylene, is inadmissible, because it may give rise to so called "hydrogen disease". With an excess of hydrogen in the flame the hydrogen is diffused into the metal and combines there energetically with free oxygen or with the oxygen of copper oxide, forming water vapor according to the reaction

$$H_2 + Cu_2O = 2Cu + H_2O.$$

Since the speed of the diffusion of hydrogen into copper is much higher than the speed of emergence from the copper of the superheated water vapor, inside the pits which form there may arise a high steam pressure, and in certain circumstances there may be an explosion of the metal at the borders of the grains.

Hydrogen starts to penetrate into copper starting as low as 400° C, and penetrates especially vigorously at a temperature above 700° C.

In brazing alloys of copper the easy volatility of some of the elements entering into their composition, such as zinc, cadmium, and manganese, must be borne in mind, and steps must be taken to avoid this phenomenon. For example, in brazing copper-zinc alloy or brasses, in order to avoid de-zinc-ing of the part in the flame when heating up the surface with a burner one should introduce the vapors of BM-1 flux.

The majority of the alloys of copper are prone to hot-shortness in the zone of the middle temperatures. In simple brasses the loss of mechanical properties is observed in the range between 200-600° C.

Taking this into account, one should not in brazing heat up parts in these alloys which are intended to bear weight or to undergo considerable loads.

The brazing of alloys of copper containing aluminum, beryllium, or silicon is made more complicated by the appearance upon the surface of the metal of oxides of these metals which are difficult to remove. The latter are carefully removed before brazing, after which the surface of the part is given a sufficient protection, before being heated up, with active fluxes.

Preparation of the bronzes referred to is carried out by pickling in a mixture of hydrochloric and nitric acids. Before brazing, copper and brasses are ordinarily subjected to pickling in a water solution of 10% sulphuric acid.

The brazing of copper and its alloys can be carried out with any of the low-melting-point solders, the copper-zinc ones, the copper-phosphorus ones, or the silver ones. In the selection of a brand of solder one is guided by general considerations (see p. 45 /of original text/). Flux is selected, depending upon the properties of the solders used, in correspondence with the properties of the latter; the system for treating the article after brazing is selected on the basis of general indications (see page 90 /of original text/).

4. Brazing Aluminum and its alloys.

Aluminum and its alloys are among the metals more difficult to melt. For a long time it was believed that they could not be brazed at all.

The difficulties encountered in brazing aluminum and its alloys are for the most part occasioned by the formation on the surface of a durable

and strong oxide film. At present, as a result of the creation of sufficiently active fluxes which will break up this oxide film, brazing of these alloys is carried out successfully enough. But one must bear in mind that the fact that existing solders have a lower resistance to corrosion than aluminum and its alloys, for which reason the admissible corrosion resistance of the brazed joint is achieved by protecting it with lacquers.

In selecting the construction of a brazed joint it is indispensable to take into account the specific properties of aluminum and of the materials used in brazing it. The size of the lap must be somewhat smaller than for other metals. This occasioned by the fact that the solders industrially available for brazing aluminum have melting temperatures relatively close to the melting temperature of the material to be melted, which brings about an elevated solubility of each in the other and hence a reduced spreading capacity of the solder upon its entering the gap. With this fact as point of departure, the size of the gap for thin-walled articles is taken as being approximately 4-5 mm., for thicker ones as being three or four times the thickness of the walls.

At the same time the size of the gap is taken as being somewhat larger than is accepted for other metals (from 0.1 to 0.3 mm).

Before brazing the article it must be carefully cleaned of dirt, grease, and oxides.

De-greasing is ordinarily accomplished in gasoline, carbon tetrachloride, and alkalis. In addition to this, it is possible to de-grease in a solution of the following composition in t per l: /presumably a misprint for "g. per l.," grams per liter/;

Trisodium phosphate	40-60
Caustic soda	8-12
water glass	25-35

The solution in the depth must have a temperature of 60-70° C. After de-greasing the part is washed in hot and then in cold water, is dried with compressed or hot air, and the spot for the braze is also cleaned with a scraper or file or by machining on the walls till it takes on a mattle color. The oxide film may be removed by the above-listed means of mechanical cleaning, but it is more reliably removed by pickling. For this purpose there is used a 10% water solution of caustic soda at a bath temperature of 20-40° C. After pickling clarification in a 10-20% solution of nitric acid, followed by careful washing in water and by drying, is recommended.

The surface of aluminum parts must be cleaned immediately before brazing or not more than 2-3 hours before brazing. Heating up in preparation for brazing should be done with the flame of a gasoline-air burner. An oxy-acetylene flame should not be used, because the fluxes used in brazing aluminum, and above all 34A flux, interact with the acetylene, as a result of which it becomes inactive.

In connection with the high heat conductivity of aluminum the flame ought to be rather strong. In brazing massive parts it is recommended that a preliminary heating to a temperature of approximately 400-450° C be undertaken.

The flux is not applied to the edges to be brazed in advance. The point of brazing is heated by the flame of the burner to the working temperature of the braze, approximately 550-600°C, then with the end of the rod of solder, which has been heated almost to the melting point, the powder-form flux is put on. Spreading on the surface of the butt, the flux dissolves the film of aluminum oxide Al_2O_3, after which the solder is applied. At this moment, in order not to overhead the solder, the flame is directed aside for a few seconds.

With a 3-mm. thickness of the basic metal, or more, the solder is melted by virtue of the heat of the part to be brazed. With lesser thicknesses the melting of the solder is carried out by heating with the flame, but, in order not to overheat it, the flame is set softer and long, and this is placed so that it barely touches the end of the solder.

After application of the flux and the solder it is still necessary to heat the brazed seam a little while in order that the solder may penetrate evenly and fill the gap. In joining thin-wall with massive parts the flame must be directed predominantly at the more massive part.

The remnants of flux are active enough to provoke corrosion and disintegration both of the seam and of the basic metal, for which reason they must be carefully removed not later than 30-40 minutes from the moment at which the brazing starts. The parts are washed with stiff bristle brushes in hot water at 50-60° C, and then in cold water with subsequent drying at 120-150° C.

In order to remove internal stresses, especially at the points of brazed seams, the articles are heat-treated (by annealing, normalization, or baking). When there is strict attention to the technological process of the brazing, and above all when there is no overheating of the article, and there is also correctly selected design of seam, its strength may exceed the strength of the basic metal; but the plasticity of the welded seam is much below the analogous characteristic secured in a welded joint.

There are set forth below the tensile strengths of butt seams in aluminum and its alloys brazed with 34A solder.

Brand of solder	A8, A0, A1	АМц	Д17	В95	АЛ2	АЛ4	АЛ11
Tensile strength of brazed seam in kg per square mm.;	Disintegration takes place in the basic material	9,8	13,6	10,4	14,2	13,6	16,5

5. Brazing of Magnesium and Its Alloys

Magnesium falls into the category of the lightest metals (specific gravity 1.74) which can be properly machined by cutting. At the same time, magnesium has a comparatively low resistance to corrosion. But at present there have been found effective methods of protecting magnesium from corrosion, which has considerably broadened the field of its use in industry.

Alloys of magnesium have low specific gravity and sufficiently high mechanical properties, for which reason they find widespread use in the automobile and aviation industries. Brazing magnesium and its alloys has thus far been inadequately studied, and it is used primarily for the correction of defects in castings. The difficulties arising in brazing magnesium are associated with the presence on the surface of chemically stable oxides of magnesium, MgO, which can be removed with the aid of active fluxes (see page 74 /of original text/). In selecting a solder for brazing alloys of magnesium one should be guided by the fact that the melting temperature should be 25-50° below the temperature at which the basic metal commences to melt. In this connection it is indispensable to bear in mind that in all alloys magnesium has a comparatively large interval between the beginning and the end of crystallization, which makes the process of brazing considerably more difficult.

In brazing this metal it is indispensable to take into account its specific properties, and above all its easy inflammability in air.

In assembling parts for brazing one must carefully remove shavings, dust, and burrs, which can become the sources of bursting into flame.

Flux for the brazing must be well dried, since if it contains moisture, as a consequence of the formation of hydroxides of magnesium upon the surface brazing becomes practically impossible. The gap in brazing magnesium alloys falls within the limits 0.1 - 0.3 millimeters. Before brazing, the parts should be carefully cleaned of dirt and oxides.

Preservative lubricants, masking paint, and the like are removed by washing in gasoline, acetone, or alcohol. Furthermore, a preservative lubricant can be removed by boiling in a 0.5-1% water solution of soda for 20-30 minutes with subsequent washing in hot water and drying at a temperature of 60-80° C.

The oxide film is removed by processing in a water solution of chromium anhydride at a concentration of 20-30 grams per liter at a temperature of 60-70° C or 150-160 grams per liter at a temperature no higher than 30° C, with subsequent washing in hot and then in cold water.

The surface of the parts at the point of brazing is carefully cleaned with a file, a steel brush, or a scraper.

The parts, prepared in this fashion, are set up in holders. The parts are fastened by one of the means recommended above (see page 82 /of original text/). It is necessary to eliminate any possibility of shavings, dust, and other dirt falling on the assembled units.

The time interval between the preparation of the parts and the brazing should not exceed five hours. As with the brazing of aluminum, the heating of the parts should be carried out with a gasoline-air burner, or with a flame formed upon the burning of gas substitutes for acetylene in mixture with air. For the same reasons as with brazing in aluminum the use of the oxy-acetylene flame is not permitted.

Technological methods in brazing magnesium and its alloys are in many respects analogous to those used in brazing aluminum. In order to avoid warping, heavy parts should be heated up to a temperature of 300-350°C before brazing. A preliminary heating in an electric furnace gives better results.

It is recommended that heating in preparation for brazing be carried out from below, so that the flame may not touch the surface upon which the solder must spread.

For good spreading of the solder into the gap of the part, it is recommended that before the solder is introduced the part be heated to 30-50° higher than the temperature at which the solder melts. As in the case of brazing aluminum, the flux is applied to the point of the braze with the tip of a rod of solder upon a part heated to a temperature of 300-350° C.

Where there is relatively large lap the flux should be applied not only to the point at which the solder is applied, but also to the opposite side. Only after the flux has melted and has flowed into the gap should one commence to apply the solder, which melts primarily by virtue of the heat of the parts to be brazed.

When the brazing is finished, at once upon the cooling of the parts remnants of fluxes and slags must be removed. The parts must first be wated in a boiling 2-3% water solution of sodium carbonate for 30-60 minutes, then in cold water containing 0.3-0.5% of bichromate, after which it is supplementarily washed, in order to remove fluoride salts, in a 20-30% solution of chromium anhydride at room temperature.

Units processed in this fashion are first washed in cold and then in hot water and are dried in a drying cabinet at a temperature of 60-70°C.

The appearance, after cleaning, of defects in the seam (pores, gas cavities, failures of solder to penetrate) are eliminated by secondary brazing.

Upon cleaning the brazed seam one should not strive to remove from it the casting skin, as this protects the metal from corrosion. But if this skin cannot be preserved, one must see to it that remnants of flux are carefully removed from the pores or gas cavities which are opened up beneath it.

After final processing of brazed seams with the purpose of increasing their corrosion resistance they should be subjected to oxidation.

VIII. MECHANIZATION OF THE PROCESS OF GAS-FLAME BRAZING

In series and mass production, in order to increase the productivity of the process, to improve its qualitative indices, and also the working conditions of the brazer, mechanization of gas brazing has been instituted at a number of enterprises. Most frequently it is the most labor-prone operations in the process that are mechanized: heating, melting of flux and of solder. The operation of assembling and stripping the parts is most frequently done manually. In this process the burner is set up stationary, and the part to be brazed is moved forward or is turned. The degree of heating of the units to be brazed is determined by the consumption of the gas mixture and the duration of their stay in the heating zone.

A number of multinozzle burners are used simultaneously to increase the speed of heating the parts details. By virtue of the use of two or more burners located in various planes it is possible to weld several elements of the article simultaneously, as in furnace brazings.

Thus, mechanized installations for gas brazing yield hardly anything in compactness and productivity to installations for brazing with high frequency currents, and also to furnace brazing, and in operating expenditures they are no less economical.

Mechanized gas brazing is conducted with the application of a flux protection. Flux is applied in the form of paste or in the form of a readily evaporating liquid. In the latter case it is automatically supplied into the flame of the burner.

The solder should be applied to the part beforehand. It is applied in the form of wire, powder, rings, or discs. The form of the solder should approach the form of the brazed joint. The best results are ensured with placing of the solder inside the unit to be brazed or at a certain distance from the zone of heat feed so that it may not melt until the article is heated to the operating temperature of brazing.

Examples of placing solder in tubular joints during mechanized brazing are given in fig 39. The quantity of solder is determined by calculation or by experiment.

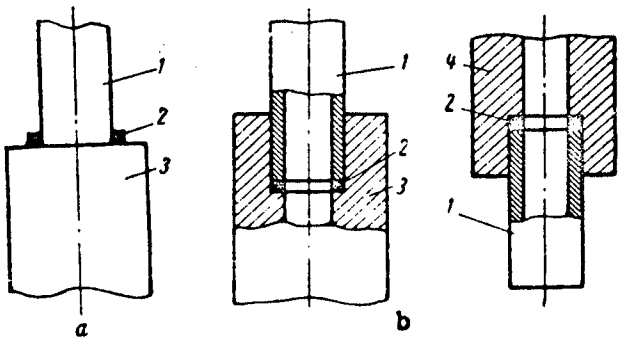


Fig. 39. Placing of solder during mechanized brazing.

a) -- incorrect b) -- correct, 1 - tube, 2 - ring of solder, 3 - mixing chamber, 4 - nipple

In order to make the process cheaper, as a rule, gas -- substitutes for acetylene (propane-butane, city gas, etc.) are used as a combustible gases.

In fig. 40 is shown an automatic machine for gas brazing with hard solders of small parts, as used abroad. Only the heating is automated in the installation. Assembly of the parts is done manually, and in doing this silver solder in the form of a ring is placed on the part. In its assembled form the article is inserted in a recess of the conveyer table. The article on the revolving conveyer pass in to the zone of heating, where the brazing takes place. The productivity of the automatic machine attain 2,000 items per hour.

The construction of a stand for brazing steel tubular furniture units (fig. 41) is of a certain interest. Brazing is done with brass solder, which is applied also in the form of a ring. Assembly of the unit is done manually. A burner with six mouthpieces is mounted on a clamp apparatus. In this way the tubular joint is simultaneously heated from all sides. Flux of type BM-1 in a gaseous state is introduced into the oxy-acetylene flame. Furthermore, before assembly there is placed on one of the tubes to be brazed a solution of boric acid to ensure fluxing inside the gap, where the flame does not strike. The presence of gasiform flux ensures a clean external surface of the unit after brazing.

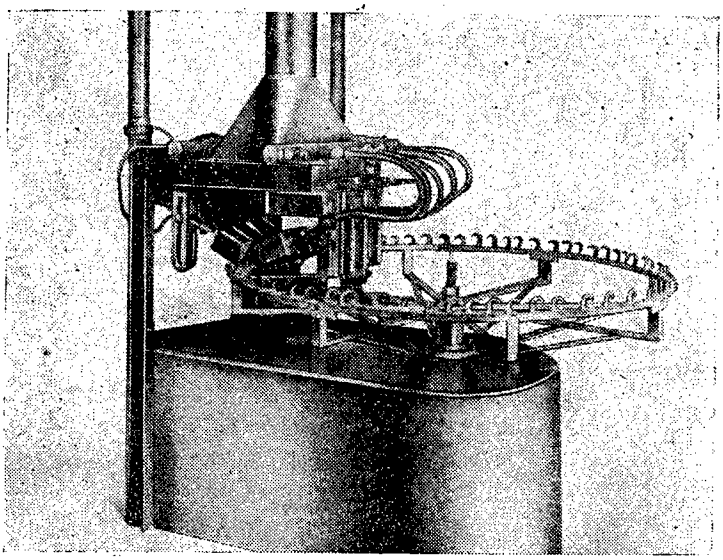


Fig. 40. Automatic machine for brazing small units.

In domestic practice SGP machines for semiautomatic gas-flame brazing have already been used successfully for a long time. (See note) They were developed with reference to the conditions governing brazing of items of gas-welding equipment ("Moscow" burners, "Plamya" cutters, etc.). Use of these machines increased productivity of the brazing section more than four times. A great economic effect through the introduction of two such machines at one of the Moscow factories was produced

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Note: VNIIAVTOGENa and MZKM design

not only by virtue of reduction of labor expenditures, but also thanks to reduction of consumption of silver solder and a shift from acetylene to Moscow city gas.

The installation provides for automation of the process of brazing with preservation of the manual operation of assembling the units to be brazed, including placing of lux in the form of paste on one of the parts to be brazed, and a solder foundation in the form of a ring.

The general form of the SGP-1-57 machine, with gas control panel, for brazing "Moscow" burner tips is shown in fig. 42. The apparatus includes an annular conveyer, a burner (2) and a gas panel (3).

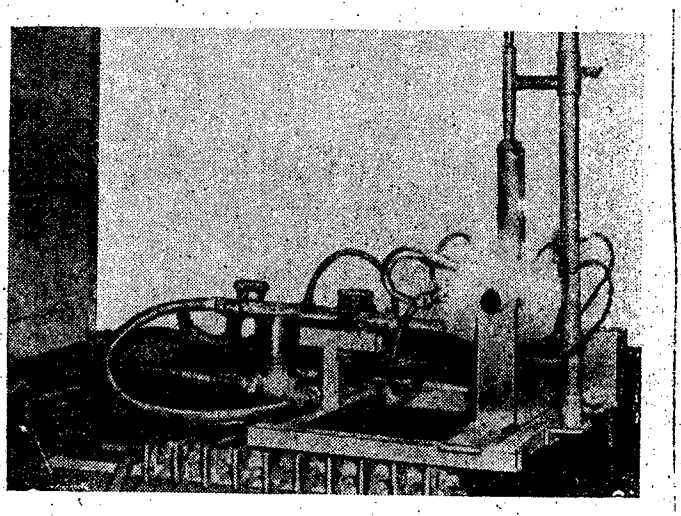


Fig. 41. Device for mechanized brazing of tubular joints

The drive of the mechanism of rotation is an electric motor of type DT-75, power 75 watts. Speed of motion of table is changed by shifting gears within limits of 0.1 -- 1.1 meters per minute. Depending upon the form of the parts subjected to brazing, special attachments, intended for setting up and fastening of parts before brazing, are installed on the table. The device, set upon a bench (fig. 42), is intended for brazing the tips of welding burners. There are set up simultaneously on the table 48 items to be subjected to brazing.

The table is divided into eight parts. On each part, which constitutes a separate section, six items are set up. Each section consists

of two hollow columns, which are fastened to the table. To the table there are also fastened two blocks for fastening the mixing chamber of the burner. Block 4 is stationary, and block 5 is mobile.

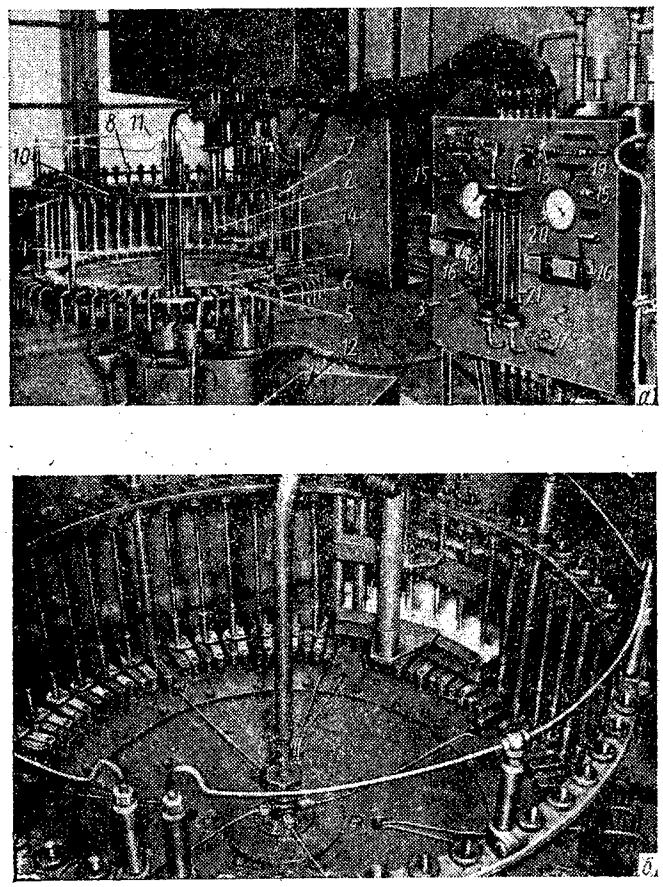


Fig. 42. SGP-1-57 Brazing bench: a) -- general view of bench, b -- conveyer of bench

The mixing chamber is fastened by handle 6, which shifts the mobile block 5, and the mixing chamber is fitted to the guide grooves of the blocks. Then handle 6 is freed and under the action of a spring resumes its original position.

This construction of the clamping mechanism permits one rapidly and with sufficient accuracy to assemble tips for brazing. After fastening the mixing chamber there is put on the tube to be brazed a nipple, by means of which the guide rod 7 is raised, and the tube inserted into the mixing chamber, being clamped in place by the mere gravity of rod 7 and weight 8. Rod 7 slides freely in bushing 9, fastened to the upper ring 10. The apparatus for fastening tips is shown in fig. 42b on a larger scale.

In brazing the columns are cooled by water, which is carried by pipes 11. Automatic dropping off of brazed tips occurs after their cooling through turning of the table by a lever, which is rigidly fastened by handle 6. As it advances upon a special wedge the lever shifts handle 6 to the point of full release of the brazed unit. Brazed tips are dropped to a special bunker 12.

Heating preparatory to brazing is carried out by multinozzle linear burners. The burners are of injector type. They consist of a mixing chamber 13 with valves, controlled from the control panel, and two radial mouthpieces, 14, which face each other. One mouthpiece is located on the outer side of the table, and the other on the inner side. The radii of curvature of the mouthpiece are equal to the radius of the table.

Oxygen and city gas are brought by hoses to the mixing chamber, where they are mixed, and the combustible mixture thus formed is directed evenly by hoses into mouthpieces.

The construction of the mouthpiece for brazing of tips of burners is shown on fig. 43.

With the help of spreader 1 in the mouthpiece the fuel mixture is distributed evenly over all its length. Into each mouthpiece there is screwed a nozzle 2, through which the fuel mixture emerges into the atmosphere. The flame is regulated by the valves of the burner. Water for cooling the mouthpiece passes through nipple 3 via channels 4, 5, 6 and emerges through nipple 7. For ignition of the flame there is fastened to the outer mouthpiece a Bunsen burner, 8. The mouthpieces are fastened to the bench by cleat 9 and column 10.

The construction of the unit for fastening burners to the bench allows one to shift mouthpieces of burners in vertical and horizontal directions, which facilitate installation of mouthpieces relative to the brazed parts of the various units. Burners for brazing the various components are set up with the use of special templates.

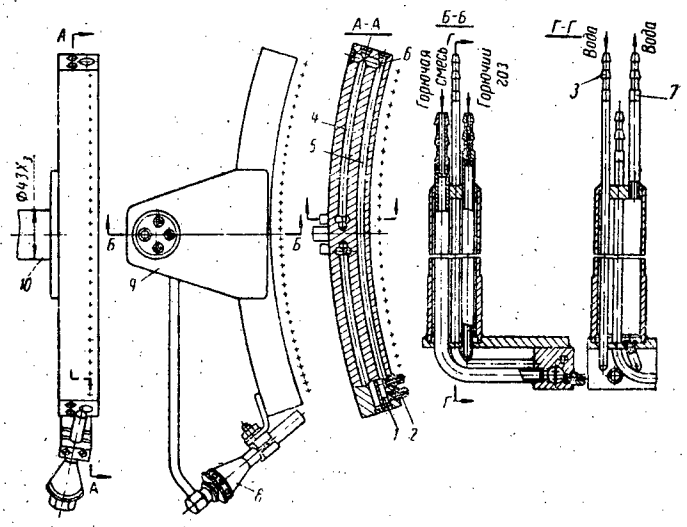


Fig. 43. Mouthpiece of burner for brazing tips.

All the gases necessary for work of the machine are led into the panel (see fig. 42), where regulation of the process of brazing is carried out. For this purpose, on the front surface of the panel there are concentrated regulating knobs, 15, of the regulators of pressure of the oxygen supplied to the burners; the gas switches 16 for shutting off of gases (extinguishing flame of burners); valves 17 and 18 for starting and adjusting of supply of cooling water; valve 19 for lighting "pilot" flame (Bunsen burners); manometers 20, showing pressure of oxygen of the entrance to the burner; mixing chambers 13 of the burners, on which are located valves for adjustment of consumption of gas; dial gauges 21, showing consumption of combustible gas.

The technological process of mechanized gas brazing consists of several consecutive operations, among which there fall preparation of the article for brazing, the process of brazing, the treatment of the article after brazing.

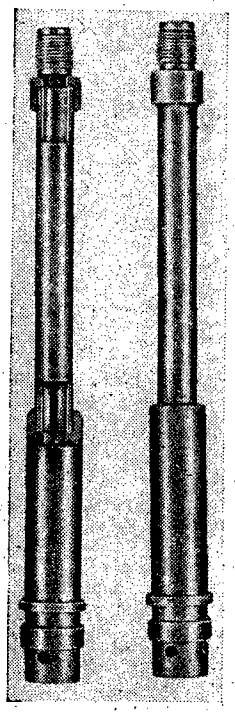


Fig. 44. "Moscow" burner tips.

The technology of preparatory operations and stripping of articles after brazing is analogous to that adopted during hand processes.

With the use of this machine there is carried out the brazing not only of "Moscow" burner tips (fig. 44), but also of more complicated units, for example the body of the "Plamya" cutter with three tubes and the body of the valve for cutting oxygen (fig. 45).

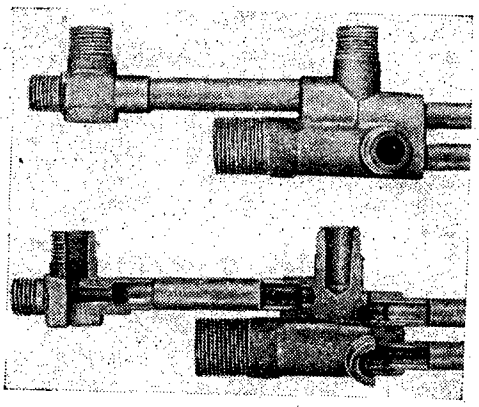


Fig. 45. Body of "Plamya" cutter with three tubes and body of valve for cutting oxygen.

In the latter case there is simultaneously carried out three-position brazing. For this purpose the machine is filled with four linear burners, one pair of which is set on a level with the juncture of the three-tube body, and the other on a level with the juncture of the tube with the body of the valve for cutting oxygen.

Simultaneous heating in the brazing of the three tubes is carried out by linear burners with rows of nozzles (fig. 46). With the help of the burners shown, by virtue of appropriate arrangement of screw-on nozzles on the flat of the mouthpiece there is ensured uniform heating of the unit to be brazed and accordingly good filling of the gap with solder in all sizes of overlap.

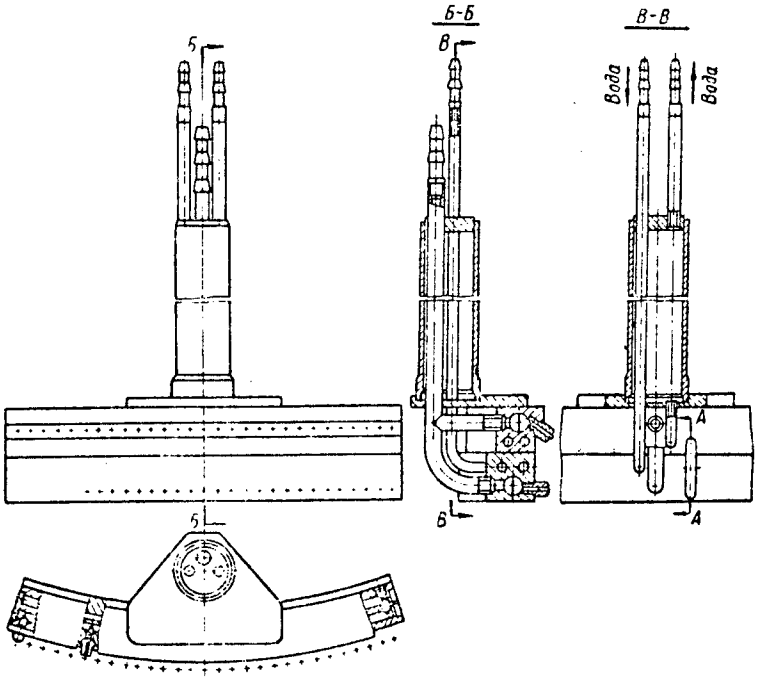


Fig. 46. Mouthpiece of burner for heating while brazing three tubes and body for "Plamya" cutter.

In doing this a strong brazed joint is obtained when there are no hollows by virtue of which consumption of solder is reduced considerably.

Technical characteristics of SGP-1-57 machine

Contour dimensions of machine in mm:	
diameter	1200
height	2000
Weight of machine in kg	474
Operating pressure of gases:	
city gas in mm, Water column	Not less than 50
oxygen in kg, per sq. cm.	3--5
Pressure of water supplied for cooling of burners in atmosphere	Not less than 0.5
Source of supply of electric power.	Three-phase alternating 3x220 volt circuit
Power consumed, watts	75
Speed of rotation of table in meters per minute	0.1--1.1
Productivity of machine, number of brazes in an hour.	700--1,000

On the SGP-1-57 machine 360 tips are brazed in an hour.

IX. Defects of Brazed Joints, Ways of Bringing Them to Light, and Methods for Eliminating Them

The quality of brazed joints depends on observance of a fixed technology and on checking the initial materials. Violating the technology can bring in its train a number of defects.

In brazing, in the overwhelming majority of cases, rejects can be repaired. For this it is necessary to release the brazes by heating the article to the melting temperature of the solder.

Fig. 47. Gap too small and solder does not flow.

Fig. 48. Misalignment of parts.

Then clean the surface, bring them together and join them anew. But this increases cost price of production, lowers quality, and lowers the productivity of labor. It is wiser to take steps to prevent the appearance of defects than to repair already finished products.

Defects (table 33) encountered in brazing may be divided into the following main groups:

a) defects of preparation and assembly of parts for brazing;
b) external and internal defects of brazed joints;
c) deformation and warping of parts to be brazed;
d) low mechanical properties of brazed joints.

Checking of quality of brazed seams should be carried out post-operationally. The method of checking is selected depending upon the requirements imposed upon the brazed article. A rough classification of methods of checking is given in fig. 50.

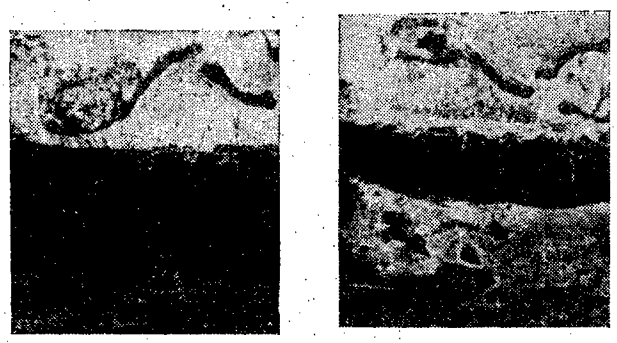


Fig. 49. Bad wetting and slag in seam.

The most wide-spread are methods of checking which do not require destructions of articles.

All articles are ordinarily subjected to external inspection by the naked eye or with the help of a magnifying glass. An indication of high quality of joint is the presence of an even and uninterrupted concave hollow on both sides. Incrustations, overflows, and also skips in the seam bear witness to low quality of joint.

A convex blister bears witness to insufficient heating or bad fluxing of brazed parts.

Airtightness of seam is checked by air pressure or liquid pressure, and also by the kerosene test. Where there is internal or external rarefaction tightness of the seam can be determined with the aid of a helium leak detector.

Table 33

Defects in brazing, causes of their appearance and methods of elimination.

Character of defect	Cause of appearance of defect	Method of prevention or elimination
Bad flowing of solder into the gap between surfaces to be brazed	Insufficient heating of parts	Increase power of flame or time of heating
	Failure of flux to flow into gap	Flux more abundantly
	Insufficient cleansing of surface of parts to be joined	Ensure most complete removal from surface of parts to be brazed of scale grease and other contaminations
	Incorrect design or assembly of brazed joint	
	Gap too small (fig. 47)	Increase size of gap
	Gap too large and no chance of filling it with its dolder	Decrease gap to that specified by drawing
	Misalignment of details during assembly; in this case solder flows only on one side (fig. 48)	Assemble in a holding jig
Overheating or even burning of metal to be brazed	High power of burner or excessive time of heating of parts	Decrease power of burner or time of heating
Slag inclusions in seam (fig. 49)	Failure of temperature of melting of flux to suit temperature of melting of solder	Select proper flux

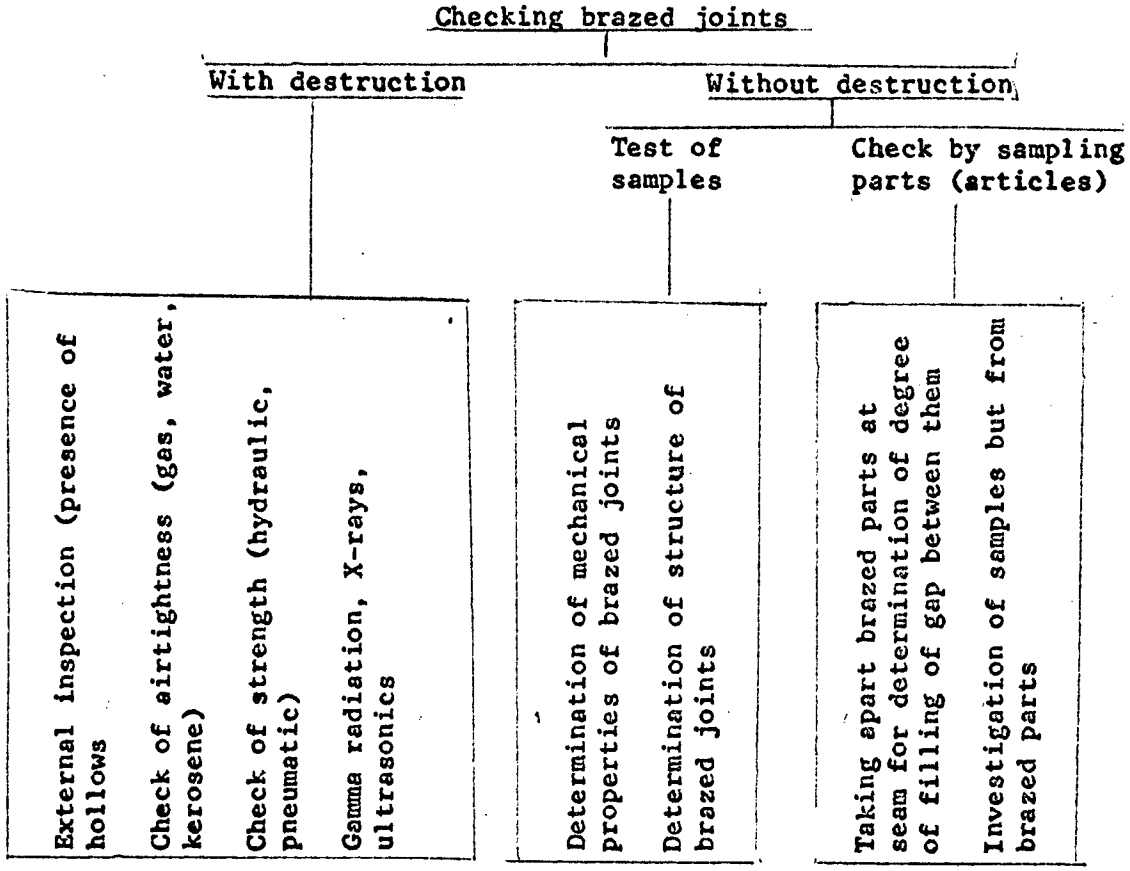
Bad wetting by solder of metal to be brazed (solder gathers in drops and does not flow into gap)	Bad preparat ion of parts for brazing; little flux, or it is insufficiently active	Clean surfaces to be brazed and sections adjacent to them or select proper flux and flux part more abundantly till it draws in the solder
Excesses of solder on external side of brazed surfaces	Uneven heating of parts. One of parts is over-heated, solder flows onto the more heated part	Heat both parts evenly at the sametime for which flame is directed upon the part which has the larger thermal capacity of the larger section

Continuity of the brazed seam (presence of gaps, pores, etc.) is checked with the help of a fluoroscope and gammascope. Sometimes to the same end an ultrasonic defectoscope is used. In particular, this method checks the quality of brazing of the heads of the s afts of turbogenerator and hydrogenerator windings.

Methods of checking involving destruction of brazed parts are used in selective tests. The degree to which the solder fills the gap between the brazed surfaces is determined by taking apart the brazed joints carried out as laps. Taking apart is done by mechanical wedging of the joined parts, heated to the temperature of where the solder softens.

Appraisal of quality of solder flow is determined in this case by the relation of the total area, covered by solder, to the area of the brazed surfaces. In a braze of good quality the area covered by solder should constitute approximately 80--95 o/o of the area of contact of the parts to be joined.

Fig. 50. Classification of methods of checking brazed joints



The mechanical properties of brazed joints (bursting, shear, impact strength, etc.) are checked on control samples. Metallographic investigation is used to determine: structure of joint, presence of overheating, burning, cracks, and other defects.

X. Safety Techniques

To the production of articles by gas-flame brazing are admitted persons of either sex not younger than 18, who have undergone instruction and passed examinations on knowledge of the rules of safety techniques.

During use of cylinders and other equipment for gas-flame treatment of metals there must be strictly observed the "Rules for Safety Techniques and Industrial Sanitation During Production of Acetylene, Oxygen, and During the Gas-Flame Treatment of Metals", approved by resolution of the

Presidium of the Central Committee of the Trade Union of Machine Building Workers on 29 September 1958 (protocol No 5).

While using acetylene from a mobile generator it is necessary to observe all rules and requirements set forth in the instructions for the use of the generator in question.

It is prohibited to work in immediate proximity to dangerously combustible and easily inflammable materials. While brazing in the open air the distance from working station to inflammable materials should be not less than 10 m.

Brazing work should be done under general and in certain cases also local ventilation. While working with propane, since the gas is heavier than air, there should be suction in the lower part of the workshop.

The burner must be carefully handled, it must be protected from damage and contamination, tightness of all joints of the burner must be checked, also absence of escape of gas, with immediate removal of defects noticed. Before lighting burner, to remove residues of air it is necessary to blow out with acetylene the hose connecting it with the water seal. In an injector burner it is necessary preliminarily to check the presence of sufficient rarefaction in the fuel gas channels upon the start of the oxygen stream through the injector. If the burner goes out, if there is "cotton-balling," or if there is blowback of flame quickly close first the hot gas cock, and then the oxygen one.

While using fluxes containing chloride or fluoride salts, brazing should be done under local ventilation. The same measures of precaution should be adopted while brazing with solders, containing cadmium, beryllium and to a degree zinc.

When working with a flame containing BM-1 flux, one must use goggles with yellow-green glass of GS-4 or GS-7 brands giving protection against the influence of ultraviolet rays.

Since methyl alcohol enters into the composition of BM-1 flux, work on filling, emptying, and washing the flux feeder, and also on pouring the fluxing liquid must be done under local draft ventilation in a rubber apron and rubber gloves, which must after working be carefully washed in running water.

If BM-1 flux falls on leather, clothes, the floor, a table or other objects in a closed locality one must wash it away with a tenfold volume of water, ventilate the premises and remove the clothing.

Brazing of magnesium alloys is done under a draft ventilation hood with strict observance of the rules of safety techniques and fire-prevention as laid down for casting, machinery, and other forms of treatment of magnesium alloys.

Literature

1. Asinovskaya, G. A.: Gas-Flame Brazing VNIIAVTOGEN. "Guidance Materials," No. 7, Mashgiz, 1955.
2. Asinovskaya, G. A.: Zelikorskaya, N. M.: Process of gas brazing and welding with gasiform flux of brand BM-1. Proceedings of VNIIAVTOGEN. Oxygen cutting welding. Mashgiz, 1959.
3. Bruker Kh. R., Bitson E. V.: Brazing in industry, Oborongiz, 1957.
4. Esenberlin, R. E.; Brazing of metals, Mashgiz, 1959.
5. Kulikov, F. V., Lekhtsner,I.R.: Hard Soldering State Power Engineering Publishing House, 1959.
6. Kulikov, F. V., Lekhtsner, I. R.: Basic methods of soft and hard soldering. Trudrezervizdat, 1958.
7. Lakedemonskiy A. V., Khryanin V. E.: Brazing and solders, Metallurgizdat, 1961.
8. Lashko N. F., Lashko-Avakyan S. V.: Brazing of metals. Mashgiz, 1959.
9. Lotsmanov, S. N.: Brazing of aluminum and its alloys. Gas-flame treatment of metals, Mashgiz, 1958.
10. Maksimikhin, B. A.: Brazing of metals in tool-making. TsBTI, L. 1959.
11. Guide to brazing of metals. Translated from English. Oborongiz, 1960.
12. Rodin, A. L.: Brazing with silver solders in the gas burner flame. Oborongiz, 1954.
13. Shashkov, A. N.: Technology of gas welding. Part I, LPI, 1937.

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